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Hydrocomp, Inc, Palo Alto, CA

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Data requirements and sources, model input and output, and model parameters are described and discussed. Extensive guidelines are provided for parameter evaluation and model calibration for runoff, sediment, pesticide, and nutrient simulation. Sample input sequences and examples of model output are included to clarify the tables describing model input and output. The manual also discusses computer requirements and methods of analysis of the continuous information provided by the model.

This manual, when used with an understanding of the simulated processes and the model algorithms, can provide a sound basis for using the ARM Model in the analysis of agricultural nonpoint pollution problems and management practices.

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USER'S MANUAL
FOR
AGRICULTURAL RUNOFF MANAGEMENT (ARM) MODEL

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FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient management tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management or engineering tools to help pollution control officials achieve water quality goals through watershed management.

These efforts include a program to provide state-of-the-art models for analyzing agricultural nonpoint pollution and evaluating the impact and effectiveness of alternative land management practices. A product of this research interest is the Agricultural Runoff Management Model, which has undergone continuous development since 1972. This document is designed to assist users in calibrating and applying the model to their specific needs.

David W. Duttweiler
Director
Environmental Research Laboratory
Athens, Georgia

ABSTRACT

This user manual provides detailed instructions and guidelines for using the Agricultural Runoff Management (ARM) Model, Versions I and II. The manual includes a brief general description of the ARM Model structure, operation, and components, but the primary purpose of this document is to supply information, or sources of information, to assist potential users in using, calibrating, and applying the ARM Model.

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This manual, when used with an understanding of the simulated processes and the model algorithms, can provide a sound basis for using the ARM Model in the analysis of agricultural nonpoint pollution problems and management practices.

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At Hydrocomp, Mr. Anthony Donigian was project manager responsible for the technical content and completion of this user manual. Mr. Harley Davis prepared the nutrient-related portions of the manual and the samples of model input and output. Mr. Douglas Beyerlein assisted in various aspects of the project and reviewed the final draft report. The manuscript was reviewed and edited by Ms. Donna Mitchell and Ms. Diana Allred. Graphics and drafting expertise was provided by Mr. Guy Funabiki, and the typing was prepared by Ms. Kathy Francies.

SECTION 1

INTRODUCTION

The purpose of this user manual is to provide detailed instructions and guidelines for application and use of existing versions of the Agricultural Runoff Management (ARM) Model. Data requirements and sources, model input and output, parameter definition and evaluation, and calibration procedures and guidelines are discussed. This manual describes the input sequence for both the original version of the ARM Model (Donigian and Crawford 1976a) and Version II (Donigian, et al. 1977). Also, the hydrologic and sediment parameters and calibration procedures and guidelines are applicable to the Nonpoint Source Pollutant Loading (NPS) Model (Donigian and Crawford 1976b) which includes similar hydrologic and sediment algorithms. This manual is not intended to replace the discussions of modeling philosophy and descriptions of model algorithms contained in the original reports. We recommend that the model user be familiar with the algorithm descriptions in the ARM Model reports since an understanding of the mechanisms and processes of agricultural runoff and their representation in the ARM Model is critical to successful application.

In general, the major steps involved in using the ARM Model are:

(1) data collection and analysis
(2) preparation of meteorologic data and model input sequence
(3) parameter evaluation
(4) model calibration and verification
(5) production of needed information and analysis of simulation results

The first three steps will often overlap as the input sequence of parameters and meteorologic data are being prepared for calibration trials. Section 2 discusses the overall structure, composition, and operation of the ARM Model while Section 3 defines general data requirements and sources. Section 4 describes the input sequence and format for model parameters and meteorologic data, and the output information obtained from the model. Examples of model output are included in Appendix B. Section 5 provides descriptions of the model parameters and guidelines for evaluation, while Section 6 discusses calibration of specific hydrology, sediment, pesticide, and nutrient parameters. Verification of simulation results is also discussed in Section 6. Section 7 explores the use and interpretation of the ARM Model simulation results for applications in environmental analysis. The appendices include sample input sequences (Appendix A), examples of model output (Appendix B), and a description of parameter input under format control (Appendix C) for computers that do not support the FORTRAN namelist option.

SECTION 2

THE AGRICULTURAL RUNOFF MANAGEMENT (ARM) MODEL

This section provides an overall description of the ARM Model and brief discussions of the present versions of the major component programs. The emphasis is on the functions and processes simulated by the component programs. The reader is referred to the ARM Model reports (Donigian and Crawford 1976a; Donigian, et al. 1977) for details of the simulation algorithms.

2.1 MODEL STRUCTURE

The ARM Model simulates runoff (including snow accumulation and melt), sediment, pesticides, and nutrient contributions to stream channels from both surface and subsurface sources. No channel routing procedures are included and uniform land use is assumed. Thus, the model is applicable to watersheds with uniform cropping and management practices that are small enough that channel processes and transformations can be assumed negligible. Although the limiting area will vary with climatic and topographic characteristics, watersheds greater than 2 to 5 sq km are approaching the upper limit of applicability of the ARM Model.

Figure 2.1 demonstrates the general structure and operation of the ARM Model. The major components of the model individually simulate the hydrologic response (LANDS) of the watershed, sediment production (SEDT), pesticide adsorption/desorption (ADSRB), pesticide degradation (DEGRAD), and nutrient transformations (NUTRNT). The executive routine, MAIN, controls the overall execution of the program; calling subroutines at proper intervals, transferring information between routines, and performing the necessary input and output functions. Table 2.1 describes the functions of each of the ARM Model components and indicates its location in the source code.

In order to simulate vertical movement and transformations of pesticides and nutrients in the soil profile, specific soil zones (and depths) are established so that the total soil mass in each zone can be specified. Total soil mass is a necessary ingredient in the pesticide adsorption/desorption reactions and nutrient transformations. Figure 2.2 depicts the zones and depths assumed in the ARM Model. The depths of the surface and upper soil zones are specified by the model input parameters, SZDPTH and UZDPTH, with values of 2 to 6 mm and 5 to 20 cm, respectively. The upper zone depth corresponds to the depth of mixing of soil-incorporated chemicals. It also indicates the depth used to calculate the mass of soil in the upper zone whether agricultural chemicals are soil-incorporated or

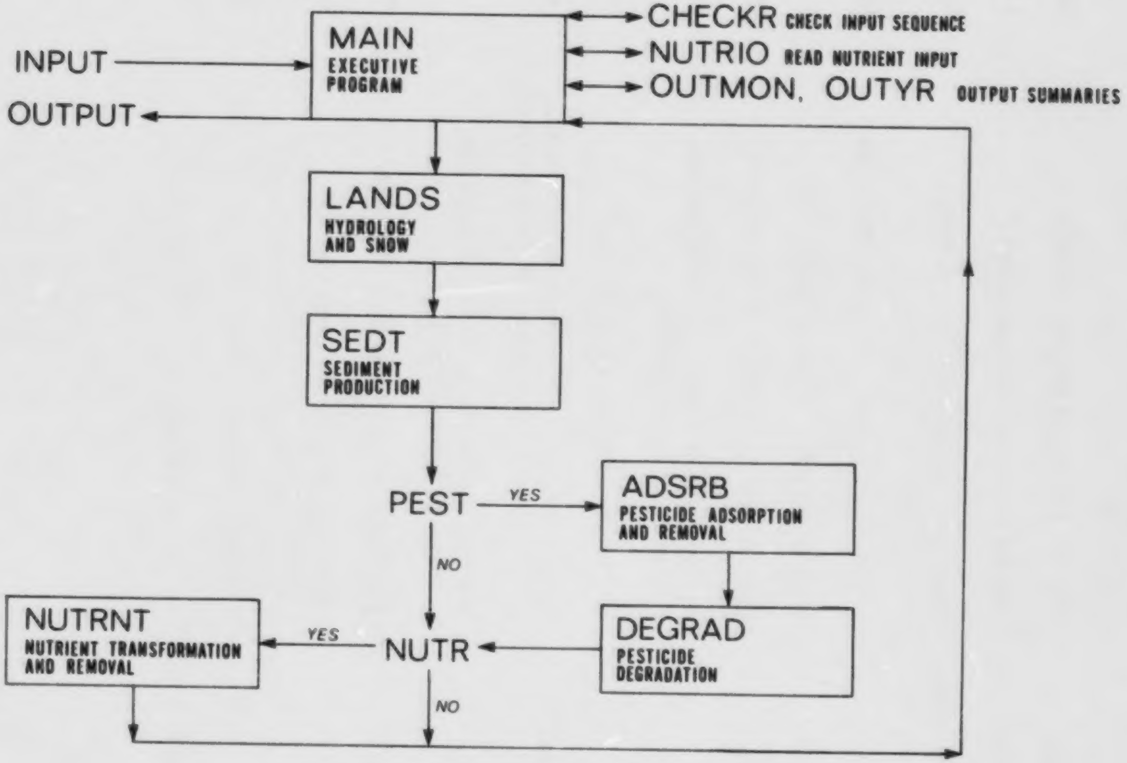

MAIN
EXECUTIVE PROGRAM
INPUT
OUTPUT
CHECKR CHECK INPUT SEQUENCE
NUTRIO READ NUTRIENT INPUT
OUTMON, OUTYR OUTPUT SUMMARIES
LANDS
HYDROLOGY AND SNOW
SEDT
SEDIMENT PRODUCTION
PEST
YES
NO
ADSRB
PESTICIDE ADSORPTION AND REMOVAL
DEGRAD
PESTICIDE DEGRADATION
NUTR
YES
NO
NUTRNT
NUTRIENT TRANSFORMATION AND REMOVAL

Figure 2.1 ARM model structure and operation

TABLE 2.1 ARM MODEL COMPONENTS

Major Program	Component Subroutine	Function	Beginning Line Number
MAIN		Master program and executive control routine	10.
	CHECKR	Checks input parameter errors	1200.
	CHECKS	Checks input parameter errors	1400.
	BLOCK DATA	Data initialization for common variables	1600.
	NUTRIO	Reads and checks nutrient input data	6200.
	OUTMON	Prints monthly output summaries	9000.
	OUTYR	Prints yearly output summaries	2000.
LANDS		Performs hydrologic simulation and snowmelt calculations	2000.
SEDT		Performs erosion simulation	4000.
	ERDBUG	Outputs to the printer erosion files written to disk (for error checking)	4200.
ADSRB		Performs pesticide soil adsorption/ desorption simulation	5000.
	DSPTN	Performs desorption calculations	5800.
DEGRAD		Performs pesticide degradation simulation	6000.
NUTRNT		Performs nutrient simulation	7000.
	TRANS	Performs nutrient transformations	7800.

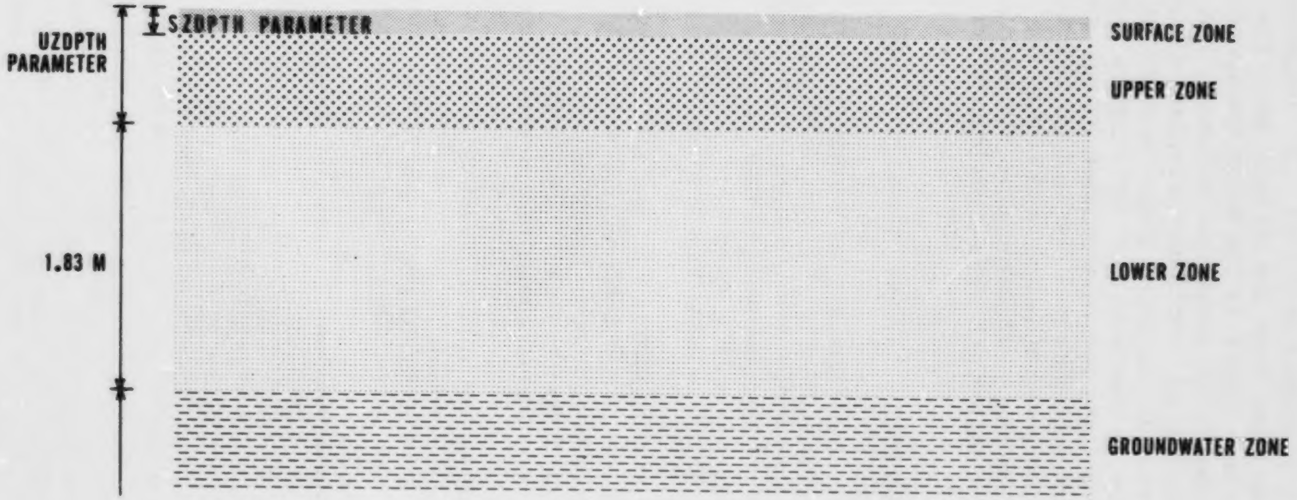

SZDPTH PARAMETER
UZDPTH PARAMETER
1.83 M
SURFACE ZONE
UPPER ZONE
LOWER ZONE
GROUNDWATER ZONE

Figure 2.2 Model soil layers for pesticide and nutrient storage

surface-applied. The lower zone depth of 1.83 m has proved satisfactory in testing to date.

The transport and vertical movement of pesticides and nutrients, as conceived in the ARM Model, is indicated in Figure 2.3. Pollutant contributions to the stream can occur from the surface zone, the upper zone, and the groundwater zone. Surface runoff is the major transport mechanism carrying dissolved chemicals, pesticide particles, sediment, and adsorbed chemicals. The interflow component of runoff can transport dissolved pesticides or nutrients occurring in the upper zone. Vertical chemical movement between the soil zones is the result of infiltrating and percolating water. From the surface, upper, and lower zones, uptake and transformation of nutrients and degradation of pesticides is allowed. On the watersheds tested, the groundwater zone has been considered a sink for deep percolating chemicals since the groundwater flow contribution has been negligible. However, on larger watersheds this contribution could be significant.

2.2 MODEL OPERATION AND COMPONENTS

The model operates on a number of different time intervals. The major interval of model operation is specified by the user and corresponds to the time interval of available precipitation data; 5- or 15-min intervals are allowed by the present version of the ARM Model. Hourly precipitation is also accepted by the model, but the hourly values are divided into four equal increments and the simulation is performed on 15-min intervals.

For days on which storms occur, the LANDS, SEDT, and ADSRB subprograms perform calculations on the 5- or 15-min interval. For days on which storms do not occur, the LANDS subprogram continues to operate on the 5- or 15-min interval while the remaining programs operate on a daily basis. In the present version of the model, the DEGRAD subprogram always operates on a daily basis, and snowmelt calculations are performed hourly. The time interval for nutrient transformations is determined by a user-specified input parameter. The MAIN program monitors the passage of real time and keys the operation of the separate subprograms at the proper time intervals. The ARM Model simulates the major processes of importance in agricultural runoff with the following components.

2.2.1 LANDS

The LANDS program simulates all flow components (surface runoff, interflow, groundwater flow) and soil moisture storages by representing the processes of interception, infiltration, overland flow, percolation, evapotranspiration, and snow accumulation and melt. LANDS is basically an accounting procedure for moisture above, at, and beneath the soil surface. It is a modification of the Stanford Watershed Model (Crawford and Linsley 1966) and Hydrocomp Simulation Programming (Hydrocomp, Inc. 1976). Snow calculations are based on an energy balance approach derived from work by the Corps of Engineers (1965), Anderson and Crawford (1964), and Anderson (1968). The LANDS algorithms are described in numerous publications

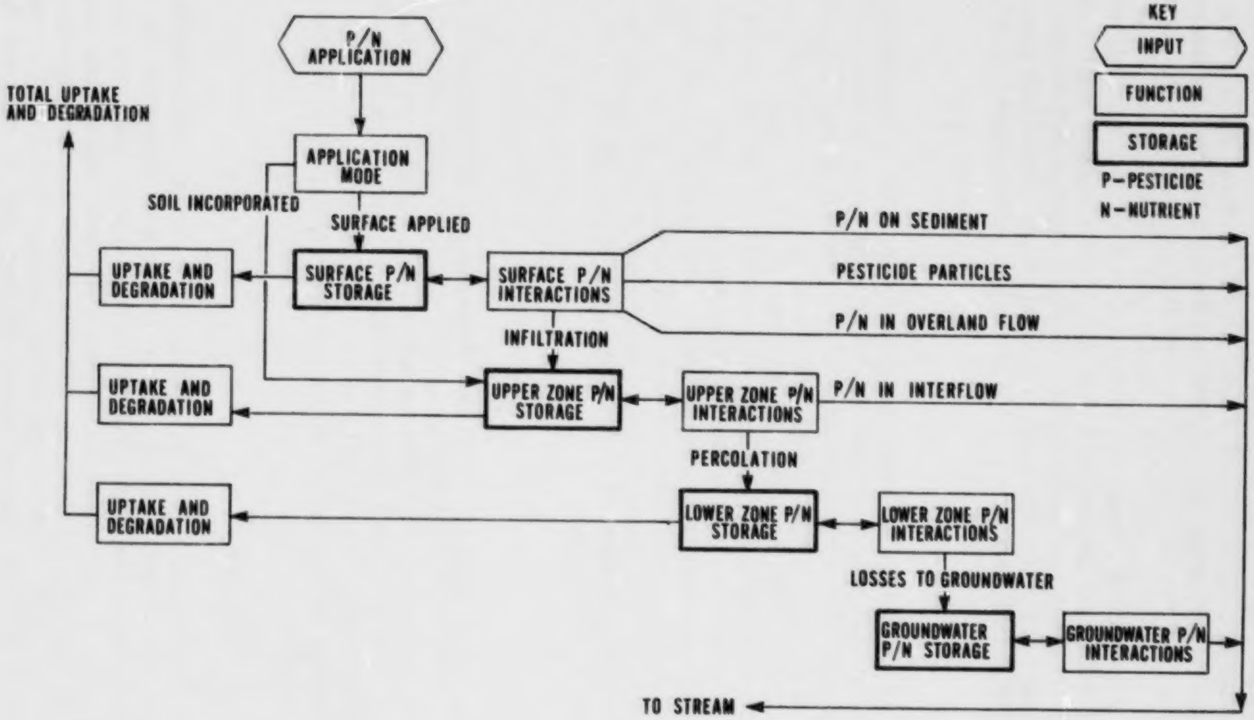

P/N APPLICATION
APPLICATION MODE
SOIL INCORPORATED
SURFACE APPLIED
TOTAL UPTAKE AND DEGRADATION
UPTAKE AND DEGRADATION
SURFACE P/N STORAGE
SURFACE P/N INTERACTIONS
INFILTRATION
UPTAKE AND DEGRADATION
UPPER ZONE P/N STORAGE
UPPER ZONE P/N INTERACTIONS
PERCOLATION
UPTAKE AND DEGRADATION
LOWER ZONE P/N STORAGE
LOWER ZONE P/N INTERACTIONS
LOSSES TO GROUNDWATER
GROUNDWATER P/N STORAGE
GROUNDWATER P/N INTERACTIONS
P/N ON SEDIMENT
PESTICIDE PARTICLES
P/N IN OVERLAND FLOW
P/N IN INTERFLOW
TO STREAM
KEY
INPUT
FUNCTION
STORAGE
P—PESTICIDE
N—NUTRIENT

Figure 2.3 Pesticide (P) and nutrient (N) movement in the ARM model

(Donigian and Crawford 1976b, Crawford and Donigian 1973; Hydrocomp, Inc. 1976) and modifications are discussed in the ARM Model reports.

2.2.2 SEDT

The SEDT program simulates the erosion processes of soil particle detachment by rainfall and transport by overland flow; overland flow values are transferred from the LANDS program. Input parameters allow the user to specify seasonal variations in land cover and the occurrence and impact of tillage operations. The SEDT algorithms were initially derived from sediment modeling research by Negev (1967) at Stanford University, and have been substantially modified during the ARM Model development work based on concepts presented by Meyer and Wischmeier (1969), Onstad and Foster (1975), and Fleming and Fahmy (1973). The SEDT algorithms and modifications are described in the ARM Model reports and by Donigian and Crawford (1976c).

2.2.3 ADSRB

The ADSRB program in conjunction with the DSPTN subroutine simulates the adsorption/desorption processes of pesticides in the soil profile. The algorithms (Figure 2.4) are modifications of a standard Freundlich isotherm plus an empirical constant, FP/M. This empirical term accounts for pesticides that are permanently adsorbed to soil particles and will not desorb under repeated washings. The user can choose to employ either single-valued, reversible (Figure 2.4a) or non-single-valued, irreversible (Figure 2.4b) adsorption/desorption equations. The operation of the algorithms is described by Donigian and Crawford (1976a, 1976c). The model (Version II) accepts initial pesticide concentrations in the soil and multiple pesticide applications, but only one pesticide can be simulated with each operation of the model.

2.2.4 DEGRAD

The DEGRAD program calculates the combined degradation of applied pesticides by volatilization, microbial degradation, and other attenuation mechanisms. A step-wise first-order daily degradation algorithm is used in the current ARM Model whereby different first-order degradation rates are specified by the user for specific time periods following application. This approach was chosen after evaluating both simpler and more sophisticated degradation models (Donigian, et al. 1977).

2.2.5 NUTRNT

The NUTRNT program in conjunction with the TRANS subroutine simulates the nitrogen and phosphorus components of runoff and transformations in the soil profile. Figure 2.5 shows the nutrient forms and transformations simulated in the current version of the nutrient model. The processes simulated include immobilization, mineralization, nitrification/denitrification, plant uptake, and adsorption/desorption. The model assumes first-order reaction rates for all transformations (except plant uptake) and is derived from work by Mehran and Tangi (1974) and Hagin and Amberger (1974). The nutrient algorithms and assumptions are fully described in the original ARM Model

Figure 2.4a Single-valued adsorption/desorption algorithm

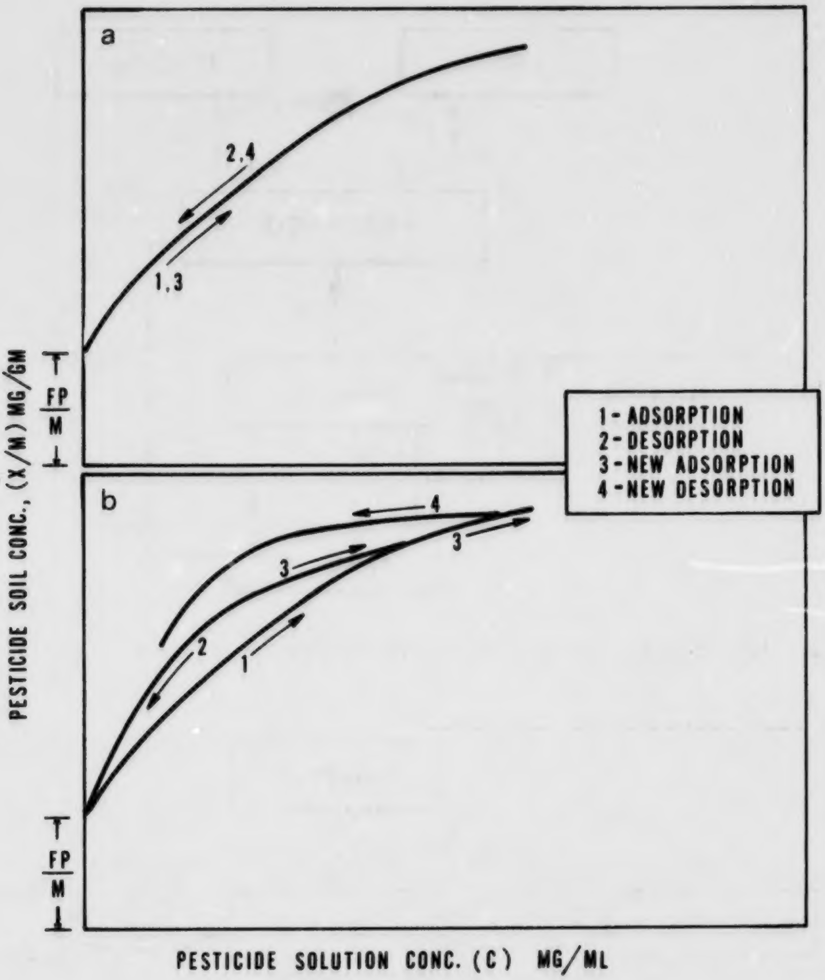
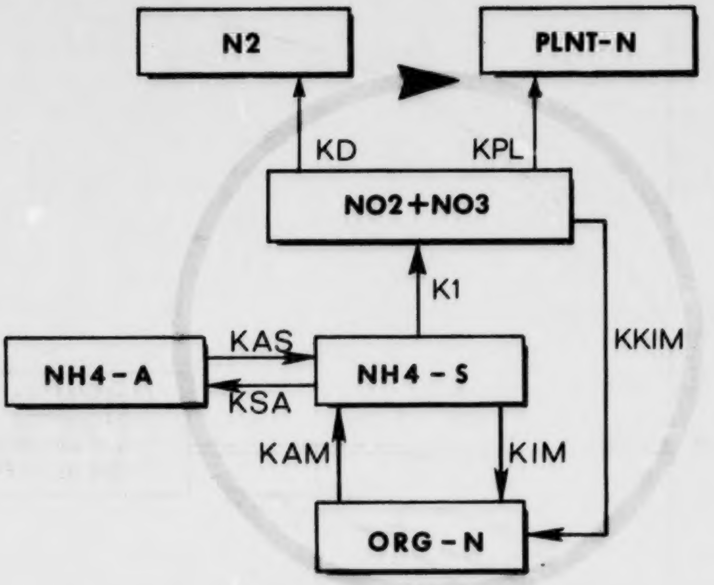
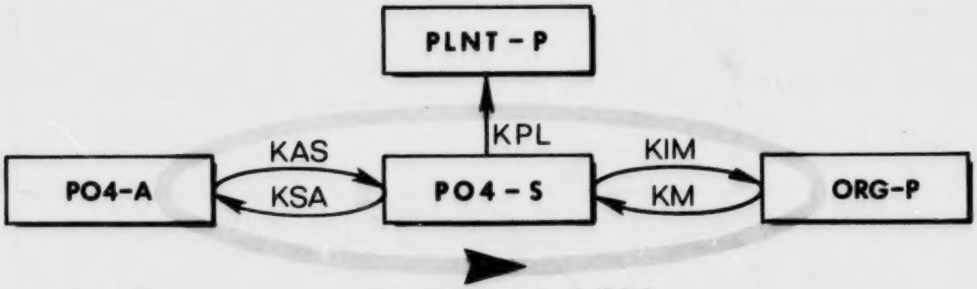


Figure 2.4b Non single-valued adsorption/desorption algorithm

Figure 2.4 Pesticide adsorption/desorption algorithms


N2
PLNT-N
KD
KPL
NO2+NO3
K1
KAS
KKIM
NH4-A
NH4-S
KSA
KAM
KIM
ORG-N

A. Nitrogen transformations in ARM model


PLNT-P
KPL
KAS
KIM
PO4-A
KSA
PO4-S
KM
ORG-P

B. Phosphorus transformations in ARM model

Figure 2.5 Nutrient transformations in the ARM Model

report (Donigian and Crawford 1976a) while substantial modifications in the ARM Model-Version II are discussed by Donigian, et al. (1977). Users of the nutrient model should be familiar with the corresponding sections of both reports.

2.3 COMPUTER REQUIREMENTS

The ARM Model is a large, relatively complex computer program comprised of 15 major subroutines and more than 5700 executable source statements written in the FORTRAN IV language. The model was originally developed on an IBM 360/67 computer and much of the model testing has been performed on an IBM 370/168, both at Stanford University. On the IBM 370/168 using the FORTRAN H compiler, the program requires approximately 360K bytes (92,000 words) of storage for compilation of the largest subroutine. Program execution requires up to 230K bytes (59,000 words) of storage depending on the model options selected. Thus, a computer with a relatively large storage capability is usually needed for use of the ARM Model. However, Version II of the ARM Model has been adapted and run on a Hewlett-Packard 3000 Series II computer which is substantially smaller than the IBM machines. Thus, the model can be used on relatively small computers; the effort and model changes needed to adapt the ARM Model to other computers will depend on the specific computer installation. Since the HP 3000 does not support the "namelist" option used for parameter input in the ARM Model, Appendix C describes the necessary changes to the program to input parameters under format control. The input format for this option is also described.

The ARM Model requires no special external storage devices (tape, disc, etc.) other than the standard card reader input and line printer output. However, the model includes an option to output simulated runoff and sediment values to an external storage device as unformatted FORTRAN records. The required input to access this output option is described in Section 4.

Table 2.2 shows the expected range of program compilation and execution time required for the ARM Model on the IBM 370/168 and the HP 3000. The smaller machine requires considerably longer time of the central processing unit (CPU). Also, execution time will vary with the specific quantities simulated (hydrology, snow, sediment, pesticides, or nutrients) and will increase with the options that produce more printed output. The values in Table 2.2 should be used as a general guide since the time requirements will vary with different computers.

TABLE 2.2 EXPECTED COMPILATION AND EXECUTION RUN TIMES FOR THE ARM MODEL[a]

	IBM 370/168	HP3000
Program compilation (min)	0.6-0.8	11.5-12.5
Program Execution (min/yr)		
hydrology and sediment (without snow)	1.5-2.0	25.0-30.0
hydrology and sediment (with snow)	1.8-2.3	30.0-35.0
hydrology, sediment, pesticide (without snow)	2.0-3.0	40.0-60.0
hydrology, sediment, pesticide (with snow)	3.0-5.0	75.0-100.0
hydrology, sediment, nutrients (without snow)	6.0-7.0	110.0-130.0
hydrology, sediment, nutrients (with snow)	7.0-8.0	140.0-160.0

[a] All values apply to simulation with 5-min precipitation data, and hourly calculations for snow and nutrients.

SECTION 3

DATA REQUIREMENTS AND SOURCES

Data requirements for use of the ARM Model include those related to model execution, parameter evaluation, and calibration/verification. These requirements and possible data sources are briefly discussed.

3.1 MODEL EXECUTION DATA

The basic data required for model execution is the input time series of meteorologic data which is the driving mechanism of the ARM Model. The data required for simulating hydrology, snowmelt, sediment, pesticides, and nutrients is shown below.

TABLE 3.1 METEOROLOGIC DATA REQUIREMENTS FOR THE ARM MODEL

Hydrology	Snowmelt	Sediment	Pesticides	Nutrients
Precipitation	Precipitation	Precipitation	Precipitation	Precipitation
Potential Evapotranspiration	Potential Evapotranspiration	Potential Evapotranspiration	Potential Evapotranspiration	Potential Evapotranspiration
	Max-Min air temperature			Max-Min air temperature
	Wind Movement			
	Solar Radiation			
	Dewpoint temperature			

Normal operation for hydrology, sediment, and pesticide simulation requires 5-min, 15-min, or hourly precipitation and daily potential evapotranspiration. In addition, nutrient simulation requires daily maximum and niminum air temperature, and snowmelt simulation further requires daily wind movement, daily solar radiation, and daily dewpoint temperature in addition to air temperature. Since the ARM Model is a continuous simulation model, the period of record needed for each data series corresponds to the length of time for which simulation is performed.

Although the model can be used to simulate short time periods or single events, should be simulated to overcome the impact of initial hydrologic and soil conditions (Section 6). The actual time period of simulation will depend on the information needed and the type of analysis being performed. There are no inherent limitation in the ARM Model on the length of the simulation period. Frequency analysis of long-term output (5 to 10 yr) can provide valuable information on the probability of nonpoint pollution from agricultural lands and management practices.

3.2 PARAMETER EVALUATION DATA

Data requirements of parameter evaluation pertain to ARM Model parameters that are evaluated largely from physical watershed and pollutant characteristics, land surface conditions, hydrologic characteristics, climate, agricultural cropping, and management practices. Section 5 will describe each parameter individually and indicate methods of evaluation, references, and specific data sources. In general, the types of information needed for parameter evaluation include:

- topographic maps
- soil maps and reports
- hydrologic/meteorologic studies
- water quality studies
- surveys of cropping and fertilizer/pesticide applications

Any investigations related to the above topics for the watershed to be simulated should be collected and analyzed as a source of information for parameter evaluation.

3.3 CALIBRATION AND VERIFICATION DATA

Calibration is the process of adjusting certain model parameters to improve agreement between recorded and simulated information. For the ARM Model, observed runoff and water quality data (that is, sediment, pesticides, and nutrients) are usually required for accurate evaluation of certain model parameters. However, many pesticide and nutrient parameters can be obtained from the literature or from laboratory analyses.

If snow simulation is performed, recorded snow depth and water equivalent information are needed to evaluate the accuracy of the simulation. Ideally, the observed data should be continuous to allow an accurate assessment of the continuous simulation produced by the ARM Model, and should extend for three years to obtain an adequate calibration of parameters. However, data availability on most watersheds seldom approaches the ideal, especially for water quality. In such circumstances, calibration will be limited to comparisons with whatever data can be obtained.

Testing, or verification, is the process of comparing observed and simulated values for a period of record which was not used in calibration. The intent is to determine the ability of the model to predict the recorded data, and thereby demonstrate its reliability. This method of testing is often called "split-sample" testing because the available data record is divided with one-half of the data used to calibrate the model and the other half used as a test to verify the model's prediction ability. Thus, the data requirements for verification are the same as for calibration except extending over a longer period. Such extensive data are generally not available for small watersheds, and is almost nonexistent for water quality. Consequently, verification in practical applications is usually performed on the entire period of record, and if possible, part of it is not used in calibration.

3.3.1 Data for Hydrologic Calibration

Hydrologic calibration involves comparison of simulated and recorded runoff volumes and individual storm hydrographs for a calibration period of 1 to 3 yr. The volume comparison can be made on a storm, daily, monthly, or yearly basis depending on the watershed area, the length of the calibration period, and the available data. Daily or monthly runoff volumes are needed to determine if the model is correctly representing seasonal variations.

Since the ARM Model simulates runoff on 5- or 15-min intervals (hourly precipitation is divided into equal 15-min increments), comparison of simulated and recorded storm hydrographs can be made only when the simulated and recorded data are on comparable time intervals. Thus, minor storms with durations less than the simulation interval and major storms with data only on 3-hr or 6-hr intervals will not provide sufficient hydrograph definition for a valid comparison. In summary, data for hydrologic calibration includes both continuous runoff volumes and selected storm hydrographs throughout the calibration period.

3.3.2 Data for Sediment, Pesticides, and Nutrient Calibration

Water quality calibration for the nonpoint pollutants simulated by the ARM Model is analogous to hydrologic calibration; simulated pollutant mass removal on a storm, daily, monthly, or yearly basis, and individual storm pollutant graphs for selected storms are compared with recorded data. Ideally, water quality calibration is limited to sediment and soil temperature parameters since the key pesticide and nutrient parameters are measurable in laboratory experiments. However, in practice, differences between laboratory and field conditions, insufficient funds for laboratory experiments, or inadequate data from the literature requires some adjustment or calibration of the pesticide adsorption coefficients, pesticides degradation rates, and nutrient transformation rates.

Since nonpoint pollution data are scarce, calibration is often reduced to comparison of grab sample measurements or selected storm pollutant graphs with the simulated values. Thus, actual data requirements for water quality calibration in the ARM Model are reduced to obtaining whatever water quality runoff data are available for the watershed. The model also provides the division between solution and adsorbed forms of the pollutants, but such recorded data are rarely available for comparison.

The ARM Model simulates soil temperatures, pesticides, and nutrient forms in the profile. Recorded data on soil temperature at various depths and at daily or more frequent intervals are needed to evaluate soil temperature regression coefficients. Similarly, pesticide and nutrient concentrations in the soil for the specific forms being simulated are needed to adjust pesticide degradation rates, nutrients transformation rates, and leaching adjustment factors.

Since such detailed data are rarely available, analogous information from watersheds with similar climatic, hydrologic, and soil conditions can be used to estimate the expected range of values for the simulation watershed.

This is a common procedure in hydrologic simultion; it will become more prevalent in water quality modeling as additional relevant data is collected on watersheds across the country.

3.4 DATA SOURCES

To satisfy the data requirements of the ARM Model, a thorough search of all possible data sources is a necessary task in the initial phase of application. Many agencies at all government levels are involved in the collection and analysis of data relevant to nonpoint source pollution. This includes meteorology, hydrologic, water quality, and land use-related information needed for application of the model.

Several federal agencies are active in monitoring and collecting of environmental data. With regard to meteorological data, the Environmental Data Service (formerly the Climatological Service, Division of the Weather Bureau) provides a comprehensive network of meteorologic stations and regularly publishes the collected data. Table 3.2 lists publications of the Environmental Data Service where selected meteorologic data can be found. Most of these publications can be found in the libraries of colleges and universities, or regional offices of the Environmental Data Service. The EPA STORET and USGS NASQAN data systems should be consulted for water quality data. The EPA STORET system includes data from many research and experimental watershed studies, including the extensive data used in the ARM Model development work. Regional EPA and USGS offices should be contacted for information and procedures to access their data bases.

Table 3.3 presents a brief summary of selected federal agencies and data categories related to nonpoint pollution that may be available. Agencies listed in Table 3.3 should be contacted during the initial data collection phase to uncover any data available for the specific watershed being simulated or watersheds with similar characteristics. The Soil Conservation Service, the Agricultural Research Service, and the EPA are the most likely agencies with data pertinent to the ARM Model.

Unfortunately, the large jurisdiction of federal agencies precludes data collection and monitoring on many small watersheds where the ARM Model would be applicable. Also, the emphasis of the federal agencies has been directed to major streams and river basins where water quality measurements include the effects of nonpoint pollution, point pollutant discharges, in-stream water use, and channel processes. Consequently, much of the available water quality data may not be directly comparable with the ARM Model simulation results; joint use of the ARM Model and a stream model may be needed.

Lacking specific data on the watershed to be simulated, research or experimental watersheds with similar characteristics can provide estimates of runoff, sediment, pesticide, or nutrient loads to evaluate the simulation results. The extensive meteorologic data collected on these experimental watersheds can be used directly if the climatic regimes are similar.

Many experimental watershed studies are conducted by federal agencies, universities, and research organizations. In 1965, the American Geophysical

TABLE 3.2 SELECTED METEOROLOGIC DATA PUBLISHED BY THE ENVIRONMENTAL DATA SERVICE[a]

Data Type		Publication[b]
Precipitation:	Daily	Climatological Data Hourly Precipitation Data
	Hourly	Hourly Precipitation Data Local Climatological Data (for selected cities)
Evaporation		Climatological Data
Max-min Air Temperature		Climatological Data Local Climatological Data (for selected cities)
Wind		Climatological Data Local Climatological Data
Solar Radiation		Climatological Data-National Summary
Dewpoint Temperature		Local Climatological Data (for selected cities)
Snowfall and Snow Depth		Climatological Data
Soil Temperature		Climatological Data

[a] formerly the Weather Bureau

[b] The National Climatic Data Center, Asheville, North Carolina can be contacted for assistance in locating published data and can provide data on magnetic tapes or punched cards.

TABLE 3.3 SELECTED FEDERAL AGENCIES AS POSSIBLE DATA SOURCES FOR THE ARM MODEL

Data Category / Agency	Climatologic[a]	Hydrologic	Water Quality	Land Use & Agricultural Practices	Soil & Geology	Topographic
Environmental Protection Agency		*	**			
U.S. Geological Survey[b]		**	*		**	**
Forest Service	*	*	*	*	*	*
Bureau of Land Management			*	*		
Soil Conservation Service	*	*		**	**	*
Bureau of Reclamation	*	*	*		*	
Agricultural Research Service	*	*	*	**	*	*

*additional source

**major involvement

[a] Publications of the Environmental Data Service listed in Table 3.2 are a major source of climatological data

[b] "Water Resources Data" is an annual publication of the USGS for each state. It provides data streamflow values at all USGS sites in the state. Also, regional offices of the USGS can often provide bi-hourly storm hydrographs for selected events.

Union conducted an inventory of representative and experimental watershed studies conducted in the United States (American Geophysics Union 1965). More recently, the U.S. Forest Service performed a survey and inventory of forest and range land watersheds with appropriate data for modeling nonpoint pollution sources (United States Department of Agriculture 1977). Leytham and Johanson (1977) have compiled an extensive list of watersheds with sediment discharge records (and supporting hydrologic, meteorologic, and land use data) including watersheds operated by the Agricultural Research Service. These publications and other watershed inventories should be consulted to locate data for application of the model.

However, there is no real substitute for data collected on the watershed to be simulated, and all efforts should be expended to uncover whatever data are available. Local, regional, and state agencies and possibly private firms located in the subject watershed can be important sources of pertinent data. Local agencies will often exhibit great interest in water quality because of direct and indirect impacts of pollution on their activities. The types of agencies that should be contacted include:

- planning commissions
- soil conservation districts
- flood control districts
- water conservancy districts
- water resource and environmental agencies
- university departments of agriculture, soil science, or engineering

Planning commissions and soil conservation districts can be a source of land use, soils, and topographic data. Flood control and water conservancy districts will often establish meteorologic stations and monitor streamflow and water quality. State water agencies and university departments are usually active in projects and investigations of water resources and water quality in the state. All agencies listed above should be consulted to provide a sound base for application of the ARM Model.

SECTION 4

MODEL INPUT AND OUTPUT

4.1 MODEL INPUT SEQUENCE

The ARM Model accepts input of parameters and meteorologic data on a sequential basis in either English or metric units. Table 4.1 demonstrates the sequence of input data; sample input listings of parameters and meteorologic data are included in Appendix A. Input of the ARM Model parameters begins the sequence. Section 5 entitled "Model Parameters and Parameter Evaluations" defines and describes the parameter input sequence.

TABLE 4.1 INPUT SEQUENCE OF PARAMETERS AND METEOROLOGIC DATA

ARM Model Parameters		
Potential Evapotranspiration		1st Year
Max-Min Air Temperature		
Wind Movement		
Solar Radiation		
Dewpoint Temperature		
Precipitation		
Potential Evapotranspiration		2nd Year
Max-Min Air Temperature		
Wind Movement		
Solar Radiation		
Dewpoint Temperature		
Precipitation		
⋮	etc.	⋮

4.1.1 Meteorologic Data Input Format and Sequence

The ARM Model parameters are followed by the meteorologic data. All meteorologic data except precipitation are input on a daily basis as a block of cards) with 12 values in each line. Thus, the resulting 31 x 12 matrix corresponds to the 12 months of the year with a maximum of 31 days each. Table 4.2 demonstrates the format for the daily meteorologic data and Table 4.3 describes units and attributes. The only change to the format in Table 4.2 is for daily max-min air temperature since two values are input for each day. In this case, the six spaces allowed for each daily value are divided in half. The first three spaces contain the maximum, and the second three spaces contain the minimum air temperature for the day.

TABLE 4.2 SAMPLE INPUT AND FORMAT FOR DAILY METEOROLOGIC DATA

	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
EVAP73	18	74	60	29	13	266	131	103	19	41	90	68	1
EVAP73	18	90	170	29	13	70	163	96	63	69	72	68	2
EVAP73	18	60	43	30	14	65	140	53	189	97	48	47	3
EVAP73	0	61	43	60	4	70	156	162	124	104	48	52	4
EVAP73	35	61	43	112	202	171	145	34	115	117	114	47	5
EVAP73	28	82	71	15	99	8	185	122	24	138	54	42	6
EVAP73	28	121	4	15	100	72	87	55	161	124	12	31	7
EVAP73	28	69	41	15	34	70	145	105	92	90	0	57	8
EVAP73	28	7	35	15	135	37	62	130	145	117	78	36	9
EVAP73	28	20	20	15	210	108	185	36	218	159	72	10	10
EVAP73	28	21	20	16	202	68	175	139	185	76	60	57	11
EVAP73	28	21	21	16	219	142	133	162	145	34	48	36	12
EVAP73	28	16	123	113	145	132	185	4	90	110	48	57	13
EVAP73	28	54	123	113	176	90	154	72	211	117	54	36	14
EVAP73	27	46	132	113	192	156	246	208	125	76	24	36	15
EVAP73	33	47	103	113	222	121	140	115	158	83	24	104	16
EVAP73	19	45	61	1	171	160	89	123	191	90	60	73	17
EVAP73	41	45	61	88	173	70	58	92	130	110	120	47	18
EVAP73	41	46	61	88	159	72	80	72	112	117	66	57	19
EVAP73	54	46	61	88	72	161	46	130	110	104	24	73	20
EVAP73	54	81	112	88	103	84	168	205	73	83	48	104	21
EVAP73	55	83	44	88	198	149	129	178	79	83	36	109	22
EVAP73	118	101	104	88	154	183	136	143	132	83	66	99	23
EVAP73	32	45	87	13	232	62	141	122	152	77	36	83	24
EVAP73	24	46	87	13	153	262	71	112	112	71	30	10	25
EVAP73	24	46	87	19	114	109	65	136	92	65	48	42	26
EVAP73	24	28	72	332	90	126	27	52	33	59	24	68	27
EVAP73	25	60	86	58	152	59	43	170	66	53	78	36	28
EVAP73	25		50	58	3	137	148	37	79	48	54	16	29
EVAP73	91		31	58	153	213	155	249	165	69	204	47	30
EVAP73	17		31		198		103	38		14		68	31
7	14	20	26	32	38	44	50	56	62	68	74	80	
Column Number													

Notes:
1. Columns 1-7 are ignored. They can be used to identify the data.
2. All data are input in integer form.
3. Identical format for evaporation, wind, solar radiation, and dewpoint temperature.
4. For Max-Min air temperature data, the six spaces allowed for each daily value (above) are divided in half; the first three spaces contain the maximum temperature, and the second three spaces contain the minimum temperature. See listing in Appendix A.

TABLE 4.3 METEOROLOGIC DATA INPUT SEQUENCE AND ATTRIBUTES*

Data	Interval	Units		Comments
		English	Metric	
Potential Evapotranspiration	Daily	in x 1000	mm	Assumed equal to lake evaporation, and lake evaporation = pan evaporation x pan coefficient
Max-Min Air Temperature	Daily	degrees F	degrees C	1. Caution: Time of observation determines whether the recorded values refer to the day of observation or the previous day. 2. Required only for nutrient and snow simulation.
Wind	Daily	miles/day	km/day	Required only for snow simulation
Solar Radiation	Daily	langleys/ day	langleys/ day	1. Total incident solar radiation. 2. Required only for snow simulation. 3. 1 langley = 1 calorie/cm^2
Dewpoint	Daily	degrees F	degrees C	1. Required only for snow simulation. 2. Average daily value since variations during the day are assumed minor.
Precipitation	5 minutes 15 minutes Hourly	in x 100	mm	

* All meteorologic data are input in integer form. Format specifications are described in Table 4.2.

Table 4.4 indicates the format for precipitation data input on 5-min, 15-min, or hourly intervals. Except for precipitation, daily meteorologic observations are needed. For hydrology, sediment, and pesticide simulation, without snowmelt calculations, only precipitation and evaporation are required in the present version of the ARM Model. For nutrient simulation, max-min air temperature is an additional requirement, and for snow simulation, the required data series include max-min air temperature, daily wind movement, daily solar radiation, and daily dewpoint temperatures (in addition to precipitation and evaporation). For further clarification of these formats, see the sample input listings in Appendix A. The model operates continuously from the beginning the the end of the simulation period. To simplify input procedures and reduce computer storage requirements, the meteorologic data are input on a calendar year basis. Each block of meteorologic data indicated in Table 4.1 must contain all daily values for the portion of the calendar year to be simulated. Thus, if the simulation period is July to February, the model reads and stores all the daily meteorologic data for the July to December period. The model then reads the precipitation data on the 5-min, 15-min, or hourly intervals, and performs the simulation day by day from July to December. When the month of December is completed, the model reads the daily meteorologic data for January and February, and then continues stepping through the simulation period by reading the precipitation and performing the simulation day by day for January and February. Thus the input data must be ordered on a calendar year basis to conform with the desired simulation period.

4.2 MODEL OUTPUT

Since the ARM Model operates chronologically on the input meteorologic data, output is provided sequentially as a function of the mode of operation, simulation options, and the frequency of printing. The user specifies the type of output desired through the use of simulation "control" parameters in the parameter input sequence (Section 5). Appendix B includes samples of all the types of model output discussed below.

The HYCAL and PRINT parameters determine the mode of model operation and the resulting frequency and extent of printed output, respectively. The two modes of operation allowed by the present version of the ARM Model are referred to as calibration (HYCAL = CALB) and production (HYCAL = PROD). The monthly and yearly summaries obtained from calibration and production runs are identical. They provide the monthly and yearly totals for runoff and loss of sediment, pesticides and nutrients, and storages of soil moisture, pesticide, and nutrient forms in the soil layers on the last day of the month or year (Table 4.5). In the examples in Appendix B, note that the word BLOCK is used to indicate the areal-source zones (see Donigian and Crawford 1976a) in order to prevent confusion with the vertical soil zones (that is, surface, upper, lower, and groundwater).

4.2.1 Calibration Output

The basic difference between the calibration and production modes is the type and form of information obtained for simulation periods between the monthly summaries. A calibration run provides detailed information on

TABLE 4.4 ARM MODEL PRECIPITATION INPUT DATA FORMAT

Column No.	Description and Format
1	Blank
2-7	Year, Month, Day (e.g. January 1, 1940 is 400101).
8	Card Number: 5 and 15 minute data - each card represents a 3-hr period. Card #1 Midnight to 3:00 AM #2 3:00 AM to 6:00 AM #3 6:00 AM to 9:00 AM . . . #8 9:00 PM to Midnight All eight cards are required if rain occurred any time during the day. A card number of 9 signifies that no rain occurred during the entire day, and no other rainfall cards are required for that day. Hourly data - Each card represents a 12-hour period; thus, two (2) cards are required for each day when precipitation occurs. Card #1 is for the 12 AM hours. As with 15-min, a card #9 indicates no precipitation occurred in that day.
9-80	Precipitation data (mm (00's of in.)). 15-min intervals: 6 column per each 15-min in the 3-hr period of each card. Number must be right justified, i.e. number must end in the 6th column for the 15-min period. 5-min intervals: 2 columns per each 5-min interval, i.e. the 15-min period still occupies 6 columns, but it is broken down into three 5-min intervals. Hourly intervals: 6 columns per each hourly interval, i.e. the hourly period occupies 6 columns, and only two cards are needed for the entire day. Number must be right-adjusted.

Notes:
1. Appendix A contains a sample of input data.
2. At least one precipitation card is required for each day of simulation.
3. Blanks are interpreted as zeros by the Model: consequently, zeros do not need to be input.
4. Only integer values are allowed.

TABLE 4.5 INFORMATION PROVIDED IN MONTHLY AND YEARLY SUMMARIES OF CALIBRATION AND PRODUCTION RUNS

Hydrology	Total runoff and components (overland flow, interflow, impervious, and baseflow) Groundwater recharge Precipitation Evapotranspiration (net and potential) Crop cover Soil moisture storages on the last simulation interval of the month or year
Snow	Precipitation as snow Rain occurring on snow cover Combined snowmelt and rain Melt components (radiation convection, condensation, rain meet, ground melt) Snowpack depth (water equivalent) and density Snow cover Snow evaporation
Sediment	Sediment loss Sediment fines storage
Pesticide	Pesticide storage (crystalline, dissolved, adsorbed) in each soil layer Pesticide loss by overland flow, interflow, and sediment Pesticide degradation loss from each soil layer
Nutrients (all nutrient forms)	Nutrient storages in each soil zone Nutrient loss by overland flow, interflow, sediment, and percolation from each soil layer Total nutrient loss to the stream Nutrient loss by transformation from each zone and by harvesting

runoff, sediment concentration and mass removal, and pesticide or nutrient concentrations and mass removal for each simulation interval (5- or 15-min). The goal of calibration output is to provide the information needed to compare simulated runoff, sediment loss, and pesticide or nutrient loss with recorded values for storm events. Since information is provided in each simulation interval the PRINT parameter must be specified for interval output (PRINT = INTR) for all calibration runs. Due to output printing limitations, pesticides and nutrients cannot be run simultaneously in the calibration mode.

4.2.2 Production Output

The production mode of operation provides summaries of runoff, sediment, pesticide, and nutrient loss, in addition to the amount of pesticide and nutrients remaining in the various soil zones. Thus, the production mode provides a complete picture of the mass balance of pesticides and nutrients applied to the watershed. Pesticide and nutrient simulation can be performed simultaneously in the production mode. The production output is printed in tables similar to the monthly summaries. The frequency of printing is controlled by the PRINT parameter which allows printing to be done on each interval (PRINT = INTR), each hour (PRINT = HOUR), or at the end of each day (PRINT = DAYS) or each month (PRINT = MNTH). Generally, production runs will be employed for daily or monthly print intervals. Use of the interval (INTR) or hourly (HOUR) printout in the production mode should be restricted to short simulation periods due to the large amount of printed output provided. For example, over 500 pages of output is provided each day of simulation for a production run which prints output for each 5-min interval.

4.2.3 Disk Output

The ARM Model Version II includes the option to write total land surface runoff (LSRO), overland flow (RROS), or erosion (EROS) simulated in each time interval to an external storage device. This capability was developed to interface the ARM Model with an in-stream sediment transport model to simulate sediment movement in large watersheds (Leytham and Johanson 1977).

With use of the proper control parameters (Section 5) the user can instruct the model to create data files of the above variables for subsequent statistical analysis or interface with stream models. Two types of data files can be created by Version II of the ARM Model: (1) uncompressed files (LSRO and RROS data), and (2) compressed files (EROS data). Both files have the following characteristics.

(1) Fixed length records: Each record contains TBLKSZ data items. TBLKSZ is the number of simulation intervals in a time block, and specifies the number of intervals simulated before the resulting block of information is written to disk. The choice of TBLKSZ affects the execution of programs that access the created data files, and an optimal value depends on the relative costs of core storage, CPU time, disk storage, and I/O operations (Leytham and Johanson 1977). The ARM Model Version II uses a time block size of 128 which was found to

minimize the amount of disk storage required for data files on the HP 3000. To change this value, the dimensions of the arrays LSRO, EROS, and RROS must be changed to the new TBLKSZ value in line 2020.1 in the LANDS program. Note that idiosyncrasies on IBM machines require unformatted files to be treated as having variable length, blocked, spanned (VBS) records.

(2) Binary files: The data are transferred to and from disk in binary form without format control. This obviates the usual conversion of data from character (ASCII or EBCDIC) form on the disk files to binary form in core, or vice versa, thus expediting data transfer.

(3) Sequential access: All data are written and must be accessed sequentially.

The first record on each file is a label which is written by the MAIN program of the ARM Model (lines 353/354) before any data are transferred. The format and contents of the label are shown in Table 4.6. Whenever a file is read, the contents of the label should be printed by the reading program so the user can check that the correct file has been accessed. The records following the label contain the data themselves in units of inches (mm) of water for LSRO and RROS files, and tons/acre (tonnes/hectare) for EROS files for the area simulated.

The data are stored in either "uncompressed" or "compressed" format. With the uncompressed format, data are stored in a purely sequential form. Successive items in the record contain data from successive simulation time intervals.

Compressed records were developed to save space when storing data for processes which occur intermittently. They are useful, for example, in storing information on simulated land surface erosion; a process which occurs only when overland flow takes place. The idea is to eliminate the large number of zeros which would otherwise appear in the file.

To achieve this, the program keeps track of the number of data intervals which have elapsed since the start of the file. When filling the buffer array in core, prior to writing to the file, nothing is stored until a nonzero value is encountered. A negative number is then written. The negative sign indicates that the number is a header or displacement indicator, and the absolute value is the displacement (in data intervals) since the start of the file. Data are then stored in succeeding elements of the array in the conventional manner until another zero value is found. This process is repeated until the array is full, at which time it is transferred to disk as a single record, whereupon the buffer array starts to fill again. A typical compressed file is shown in Figure 4.1.

The compressed format has been used to store erosion data simulated for Four Mile Creek, Iowa. The files occupy only 5 percent of the disk space which equivalent files in uncompressed format would require. In general, the degree of compression achieved will depend on how intermittent the process is.

TABLE 4.6 FILE LABEL FORMAT

Element Number	Contents	
1-20	Descriptive title for contents of the file. Title may consist of up to 80 alpha-numeric characters.	
21	Starting hour of the file (File starts with the first interval of this hour.)	
22	Starting date of the file	
23	Starting month of the file	
24	Starting year of the file	
25	Ending hour of the file (File ends with the last interval of this hour.)	
26	Ending day of the file	
27	Ending month of the file	
28	Ending year of the file	
29	File time interval in seconds	
30	File type = 1	uncompressed diffuse load file (LSRO)
	File type = 2	compressed diffuse load file (EROS)
	File type = 3	uncompressed point load file
31	TBLKSZ - not used	

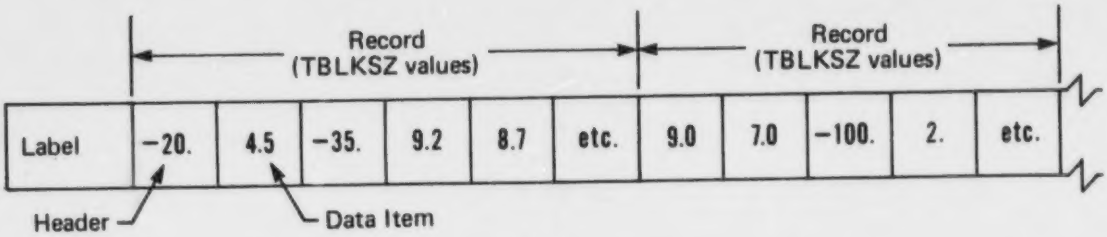

Record
(TBLKSZ values)
Record
(TBLKSZ values)
Label
−20.
4.5
−35.
9.2
8.7
etc.
9.0
7.0
−100.
2.
etc.
Header
Data Item

Figure 4.1 Format of compressed record

The compressed format has been used to store erosion data simulated for Four Mile Creek, Iowa. The files occupy only 5 percent of the disk space which equivalent files in uncompressed format would require. In general, the degree of compression achieved will depend on how intermittent the process is.

SECTION 5

MODEL PARAMETERS AND PARAMETER EVALUATION

5.1 ARM MODEL PARAMETERS

The ARM Model includes parameters that must be evaluated whenever the model is applied to a specific watershed. Since the model is designed to be applicable to watersheds across the country, the parameters provide the mechanism to adjust the simulation for the specific topographic, hydrologic, soil, and land management conditions of the watershed. The large majority of the parameters are easily evaluated from known watershed characteristics. Parameters that cannot be precisely determined in this manner must be evaluated through calibration with recorded data. This section discusses and defines the ARM Model parameters, the parameter input sequence, and methods of parameter evaluation. Section 6 provides calibration procedures and guidelines.

Table 5.1 includes a complete list and description of the ARM Model parameters. They are listed by categories: control, hydrology, snow, sediment, pesticide, and nutrients (reaction rates and storages). The control parameters allow the user to specify the mode of operation, the units and type of input and output, and the specific simulation options used in each model run. The remaining parameters describe watershed conditions, pollutant characteristics, and/or agricultural practices and are used in the simulation algorithms contained in the ARM Model.

In Table 5.1, parameters enclosed in brackets [ ] are included only in Version II of the ARM Model, whereas parameters enclosed in parentheses ( ) are included in both versions, but application/definition of the parameter has been modified in Version II. The modifications are subsequently described in footnotes in Table 5.1. All remaining parameters are identical in both model versions.

5.1.1 Control Parameters

The HYCAL and PRINT parameters are discussed in Section 4.2; they control the mode of operation and frequency of printing output, respectively. The INPUT and OUTPUT parameters specify the units of the input information (parameters and meteorologic data) and the desired units of output, respectively, either English (ENGL) or metric (METR). Also, with OUTPUT= BOTH, production mode output and summaries (monthly and yearly) in calibration mode output are provided in both sets of units. This option should be used sparingly due to the vast amount of resulting computer

TABLE 5.1 ARM MODEL INPUT PARAMETER DESCRIPTION[a]

TYPE	NAME	DESCRIPTION
Control	HYCAL	Specifies type of information desired PROD-production run, prints full tables for each interval as specified by PRINT CALB-calibration run, prints removal values for each interval as specified by PRINT
	INPUT	Input units, ENGL-english, METR-metric
	OUTPUT	Output units, ENGL-english, METR-metric, BOTH-both
	PRINT	Denotes the interval of printed output, INTR-each interval, HOUR-each hour, DAYS-each day, MNTH-each month
	SNOW	NO-snowmelt not performed, YES,snowmelt calculations performed
	PEST	NO-pesticides not performed, YES-pesticide calculations performed
	NUTR	NO-nutrients not performed, YES-nutrients calculations performed
	ICHECK	ON-checks most of the hydrology, snow (if used), sediment, and pesticide (if used) input parameter values and prints out error and warning statements for input parameter values that are outside of acceptable value limits, OFF-no check is made
	[DISK]	NO-no output written to disk YES-LSRO, RROS, and/or EROS written to disk
	[IDEBUG]	OFF-no output to check values written to disk ON-print echo of output written to disk
	[CHAR]	RUNOFF-Lands Surface RunOff (LSRO) output SEDIMENT-EROSion (EROS) from sediment output OVERLAND-Runoff fRom Overland Surface (RROS) output
	[TITLE]	Title for data set on disk (80 char)
	[DSNFLO]	Data set number for LSRO file
	[DSNERS]	Data set number for EROS file
	[DSNROS]	Data set number for RROS file
	INTRVL	Time interval of operation (5, 15, or 60 minutes)
	HYMIN	Minimum flow for printed calibration output during a time interval
	AREA	Watershed area
	BGNDAY BGNMON BGNYR	Date simulation begins-day, month, year
	ENDDAY ENDMON ENDYR	Date simulation ends-day, month, year

(continued)

TABLE 5.1 (continued)

TYPE	NAME	DESCRIPTION
Hydrology	UZSN	Nominal upper zone soil moisture storage
	UZS	Initial upper zone soil moisture storage
	LZSN	Nominal lower zone soil moisture storage
	LZS	Initial lower zone soil moisture storage
	L	Length of overland flow to channel
	SS	Average overland flow slope
	NN	Manning's n for overland flow
	A	Fraction of area that is impervious
	EPXM	Maximum interception storage
	PETMUL	Potential evapotranspiration data correction factor
	(K3[b])	Index to actual evaporation on a monthly basis (12 values)
	INFIL	Mean infiltration rate
	INTER	Interflow parameter, alters runoff timing
	IRC	Interflow recession rate
	K24L	Fraction of groundwater recharge percolating to deep groundwater
	KK24	Groundwater recession rate
	K24EL	Fraction of watershed area where groundwater is within reach of vegetation
	SGW	Initial groundwater storage
	GWS	Initial groundwater slope
	KV	Parameter to allow variable recession rate for groundwater discharge
	ICS	Initial interception storage
	OFS	Initial overland flow storage
	IFS	Initial interflow storage
Snow	[SNOWPRINT]	NO-hourly snow tables not printed during snow pack periods YES-hourly snow tables printed
	RADCON	Correction factor for radiation melt
	CCFAC	Correction factor for condensation and convection melt
	SCF	Snow correction factor for raingage catch deficiency
	ELDIF	Elevation difference from temperature station to mean watershed elevation
	IDNS	Initial density of new snow
	F	Fraction of watershed with complete forest cover
	DGM	Daily groundmelt
	WC	Water content of snowpack by weight
	MPACK	Water equivalent of snowpack for complete watershed coverage
	EVAPSN	Correction factor for snow evaporation
	MELEV	Mean elevation of watershed
	TSNOW	Temperature below which precipitation becomes snow

(continued)

TABLE 5.1 (continued)

TYPE	NAME	DESCRIPTION
	PACK	Initial water equivalent of snowpack
	DEPTH	Initial depth of snowpack
	PETMIN	Minimum temperature at which PET occurs
	PETMAX	Temperature at which PET is reduced by 50 percent
	WMUL	Wind data correction factor
	RMUL	Radiation data correction factor
	KUGI	Index to forest density and undergrowth
Sediment	COVPMO	Fraction of crop cover on a monthly basis (12 values)
	(TIMTIL)[c]	Time when soil is tilled (Julian day, i.e. day of the year, e.g. January 1 = 1, December 31 = 365/366) (12 dates)
	(YRTIL)[c]	Corresponding year (last two digits only) for TIMTIL (12 values)
	(SRERTL)[c]	Fine deposits produced by tillage corresponding to TIMTIL and YRTIL (12 values)
	JRER	Exponent of rainfall intensity in soil splash equation
	KRER	Coefficient in soil splash equation
	JSER	Exponent of overland flow in sediment washoff equation
	KSER	Coefficient in sediment washoff equation
	SRERI	Initial fines deposit
	[SCMPAC]	Rate by which soil fines are decreased per day on non-rain days
Pesticide	PESTICIDE	Title word to begin the reading of pesticide input parameters
	APMODE	Application mode, SURF-surface applied, SOIL-soil incorporated
	DESORP	NO-single-valued adsorption/desorption used, YES-non-single-valued adsorption/desorption algorithm used
	[PSSZ][d]	Initial pesticide storage in surface zone
	[PSUZ][d]	Initial pesticide storage in upper zone
	[PSLZ][d]	Initial pesticide storage in lower zone
	[PSGZ][d]	Initial pesticide storage in groundwater zone
	(TIMAP)[d]	Time of pesticide application (Julian day) (12 values)
	(YEARAP)[d]	Year of pesticide application (last two digits only) (12 values)
	(SSTR)[de]	Pesticide application for entire watershed (12 values)
	CMAX	Maximum solubility of pesticide in water
	DD	Permanent fixed adsorption capacity
	K	Coefficient in Freundlich adsorption equation
	N	Exponent in Freundlich adsorption equation
	NP	Exponent in Freundlich desorption equation
	[DDG][f]	Julian day when KDG(1) begins (max. of 12 values)
	[YDG][f]	Corresponding year in which KDG applies
	[KDG][f]	Pesticide decay rate (per day) (max. 12 values)

(continued)

TABLE 5.1 (continued)

TYPE	NAME	DESCRIPTION
Soil	[LZTEMP]	Lower zone temperature on a monthly basis (12 values)
	[AXZT]	Slope of surface zone soil temperature regression
	[BSZT]	y-intercept of surface zone soil temperature regression equation
	[AUZT]	Slope of upper zone soil temperature regression equation
	[BUZT]	y-intercept of upper zone soil temperature regression equation
	SZDPTH	Surface layer soil depth
	UZDPTH	Upper zone depth or depth of soil incorporation
	[BDSZ][g]	Bulk density of surface zone soil
	[BDUZ][g]	Bulk density of upper zone soil
	[BDLZ][g]	Bulk density of lower zone soil
	[UZF]	Upper zone chemical percolation factor
	[LZF]	Lower zone chemical percolation factor
Nutrient		
	TSTEP	Timestep of chemical and biological transformations, must be an integer number of time steps in a day, and an integer number of simulation intervals (INTRVL) in a TSTEP, range of TSTEP is 5 or 15-min to 1440 minutes, but the solution technique works best at 60 minutes or less.
	NAPPL	Number of fertilizer applications, values may range from 0 to 5
	TIMHAR	Time of plant harvesting, Julian day of the year, value may range from 0 to 366
	[ULUPTK]	Fraction of maximum crop uptake of nutrients for the the upper layers (surface and upper zone) on a monthly basis (12 values), should be 1.0 or less
	[LZUPTK]	Fraction of maximum crop uptake of nutrients for the lower zone on a monthly basis (12 values), should be 1.0 or less
Nitrogen Reaction Rates [h]		
	(K1) [i,j]	Nitrification (Oxidation) rate of solution ammonium to combined nitrite and nitrate
	(KD) [i]	Denitrification (Reduction) rate of nitrite and nitrate to gaseous nitrogen
	(KPL) [i,k]	Uptake rate of nitrate by plants
	KAM	Ammonification or mineralization rate of ORG-N to ammonium in solution
	KIM	Immobilization rate of solution ammonium to ORG-N
	KKIM	Immobilization rate of nitrate (and nitrite) to ORG-N
	KSA	Transfer rate of ammonium from solution to adsorbed (adsorption)

(continued)

TABLE 5.1 (continued)

TYPE	NAME	DESCRIPTION
	KAS	Transfer rate of ammonium from adsorbed to solution (desorption)
Phosphorus Reaction Rates[h]		
	KM	Mineralization rate of ORG-P to solution phosphate
	KIM	Immobilization rate of solution phosphate to ORG-P
	KPL	Uptake rate of phosphate in solution by plants
	KSA	Exchange rate of phosphate from solution to adsorbed form
	KAS	Transfer rate of phosphate from adsorbed to solution form
	THKM	Temperature coefficients for corresponding reaction rates, e.g. THKM is coefficient for the KM rate.
Nitrogen Storages		
	ORG-N	Organic nitrogen in or attached to soil
	NH4-S	Ammonium in solution
	NH4-A	Ammonium adsorbed to soil
	(NO2+NO3)[i]	Nitrite and nitrate
	N2	Gaseous nitrogen forms from denitrification
	PLNT-N	Plant nitrogen
Phosphorus Storages		
	ORG-P	Organic phosphorus in or attached to soil
	P04-S	Phosphate in solution
	P04-A	Phosphate adsorbed to soil
	PLNT-P	Plant phosphorus
Chloride Storage		
	CL	Chloride

[a] [ ] designate parameters added to Version II of the ARM Model (Donigian, et al. 1977) while ( ) indicate parameters whose application/definition has been modified from Version I (Donigian and Crawford 1976a) to Version II. The remaining parameters are identical.

[b] Version I includes a single average annual value for K3 while Version II requires input of 12 monthly K3 values.

[c] Version I accepts 5 values for TIMTIL, YRTIL, and SRERTL, while Version II accepts 12 values.

[d] Version I allows only a single pesticide application as specified by TIMAP, YEARAP, and SSTR; Version II allows up to 12 values (i.e. pesticide applications) for these parameters in addition to the

(continued)

TABLE 5.1 (continued)

capability to initialize the pesticide storage in each zone (i.e. PSSZ, PSUZ, PSLZ, PSGZ parameters)

[e] In Version I, the 5 values for SSTR pertain to the 5 areal blocks and the total application is the sum of the 5 values; whereas in Version II each SSTR value is the total pesticide application to the entire watershed and 12 separate application values are allowed.

[f] Version I requires a single pesticide degradation note, DEGCON, while Version II allows up to 12 degradation rates applicable to specific time periods, specified by DDG and YDG.

[g] Version I required the same soil bulk density value, BULKD for all soil zones, whereas Version II allows different values for the surface (BDSZ), upper (BDUZ), and lower (BDLZ) zones.

[h] All nitrogen and phosphorus reactions have been changed from being based on nutrient mass/hectare in each zone in Version I, to nutrient concentrations in Version II (Donigian, et al. 1977 pp. 63-68) to eliminate reactions at low moisture levels.

[i] Version I simulates NO_2 and NO_3 separately while Version II includes combined $NO_2 + NO_3$, which is assumed to be mostly NO_3 except for short periods when NO_2 is present. Thus, the K2 and KK2 transformation rates between NO_2 and NO_3 have been eliminated in Version II, and K1, KD, and KPL rates apply to the combined $NO_2 + NO_3$ form.

[j] In Version I, the K1 rate applies to transformations from adsorbed and solution ammonium to NO_2, while in Version II the K1 rate applies to the pathway from solution ammonium to the combined $NO_2 + NO_3$. The nitrification path from absorbed ammonium has been eliminated.

[k] In Version I, KPL is multiplied by the crop canopy to obtain the seasonal variation in plant uptake, whereas Version II includes the ULUPTK and LZUPTK parameters to specify the monthly distribution of plant uptake.

printout. The calibration mode output for storm events is provided in a mixed set of units (Appendix B). For example, solution concentrations are always in mg/l, to simplify comparison of simulated and recorded values in the calibration process.

Hydrology and sediment calculations are performed in each model run. However, the user-specified SNOW, PEST, and NUTR control parameters specify whether or not snowmelt, pesticide, or nutrient calculations, respectively, will also be performed. As indicated above, pesticide and nutrient calculations can be performed simultaneously in a production run but not in a calibration run. An error message will be printed and execution will be prevented if this rule is violated.

The ICHECK control parameter allows the user to direct the ARM Model to check for errors and reasonableness of the parameter values; the CHECKR and CHECKS subroutines perform this function. With ICHECK=ON, the model checks the input sequence, indicates errors, and then stops if any errors are found. After errors have been corrected the model can be run again with ICHECK=ON in order to check corrections and to perform the simulations.

The DISK control parameter is used to activate the option to write land surface runoff (LSRO), overland flow runoff (RROS), or erosion (EROS) values to an external storage device, usually a magnetic disk or tape (Section 4.2.3). With DISK=YES, the IDEBUG, CHAR, TITLE, and data set number or numbers (DSNFLO, DSNERS, DSNROS) must be specified in the input sequence. The IDEBUG parameter (ON or OFF) allows the user to have the model print in the model output the values written to the external storage device. This can be used to check the option or obtain a record of the data set. The CHAR parameter is a keyword (RUNOFF, SEDIMENT, or OVERLAND) to indicate the information written to the device, and is followed by the user-specified TITLE (80 characters maximum) of the data set and the data set number. Thus the CHAR, TITLE, and data set number must be ordered in sequence for each file written to the external storage device. Any one or all of the LSRO, RROS, and EROS files can be written to the external device in a single run. For example, the proper sequence for writing LSRO and EROS files would be:

```
DISK=YES
IDEBUG=ON
RUNOFF
<TITLE OF THE RUNOFF FILE>
DNSFLO=<10>
SEDIMENT
<TITLE OF THE SEDIMENT FILE>
DSNERS=<11>
ENDDISK
```

The information contained in <> is user-supplied. This sequence would write the LSRO file to data set number 10 and the EROS file to data set number 11. The character string ENDDISK is used to indicate the end of information for writing to the external device.

The remaining control parameters specify the simulation interval (INTRVL), the minimum flow for hydrograph output (HYMIN), the area of the watershed (AREA), and the beginning and ending dates of simulation.

5.2 PARAMETER INPUT SEQUENCE

As shown in Table 4.1, both parameters and meteorologic data are input on a sequential basis. Model parameters are input in two different formats depending on the simulation options chosen. The majority of the ARM Model parameters (except the control and nutrient parameters) are input in the FORTRAN namelist format. The input sequence and attributes for these parameters are described in Table 5.2. The nutrient parameters (except for the "nutrient control" parameters) are input under format control due to the number of transformations, reaction rates, and storages which must be defined. Table 5.3 describes the input sequence and attributes for the nutrient parameters. Study of Tables 5.2 and 5.3 and comparison with the sample parameter input listings in Appendix A should clarify the ordering of the parameter input sequence for any desired simulation run.

As in Table 5.1, the brackets in Tables 5.2 and 5.3 indicate parameters added to Version II of the ARM Model, parentheses indicate parameters whose application/definition have been modified, and the modifications are described in footnotes in the tables.

The first two lines of the input sequence provide space for specifying the watershed name, pesticide or chemical name, and other information describing the model run. Next, the control parameters described above and three control namelists (CNTL, STRT, ENDD) are input.

Next in sequence are the five hydrologic parameter namelist statements (LND1, LND2, LND3, LND4, and LND5). If snowmelt simulation is specified by the SNOW control parameter (SNOW=YES), the next parameter is SNOWPRINT= (YES or NO) followed by the four snow namelist statements (SNO1, SNO2, SNO3, and SNO4). SNOWPRINT=NO suppresses the printing of hourly snowmelt output in the form of daily tables (Appendix B).

The hydrology and snow namelists are followed by the sediment namelist statements (CROP, MUD1, MUD2, MUD3, and SMDL). If neither pesticides nor nutrients are being simulated, SMDL is the final namelist statement in the input sequence before the meteorologic data. However, if pesticide simulation is to be performed, the SMDL namelist is followed by the title word PESTICIDE (starting in column 1), the pesticide parameters APMODE= (SURF or SOIL), DESORP=(YES or NO), and the pesticide namelist statements (PSTR, PST1, PST2, PST3, AMDL, DEGD, DEGY, DEGR). If nutrient simulation is not also being performed, the soil namelist statement, DPTH, follows the DEGR namelist. Otherwise the nutrient parameters follow DEGR. The DPTH namelist is required for either pesticide or nutrient simulation. This completes the parameter input sequence for hydrology, sediment, and pesticides.

TABLE 5.2 ARM MODEL (VERSIONS I AND II) INPUT SEQUENCE AND PARAMETER ATTRIBUTES
(Excluding Nutrient Input and Parameters)

Namelist Name	Parameter Name	Type	English Units	Metric Units
	Watershed name (up to 72 characters)			
	Chemical name and/or run information (up to 80 characters)			
	HYCAL	character		
	INPUT	character		
	OUTPUT	character		
	PRINT	character		
	SNOW	character		
	PEST	character		
	NUTR	character		
	ICHECK	character		
	[DISK]	character		
	[IDEBUG]	character		
	[CHAR]	character		
	[TITLE]	(up to 80 characters)		
	[DSNFLO]	integer		
	[DSNERO]	integer		
	[DSNROS]	integer		
	[ENDDISK]	character (string ENDDISK indicates end of information for writing to disk)		
CNTL	INTRVL	integer	minutes	minutes
	HYMIN	real	cubic feet/sec	cubic meters/sec
	AREA	real	acres	hectares
STRT	BGNDAY	integer		
	BGNMON	integer		
	BGNYR	integer		
ENDD	ENDDAY	integer		
	ENDMON	integer		
	ENDYR	integer		
LND1	UZSN	real	inches	millimeters
	UZS	real	inches	millimeters
	LZSN	real	inches	millimeters
	LZS	real	inches	millimeters
(LND2)[b]	L	real	feet	meters
	SS	real		
	NN	real		
	A	real		
	EPXM	real	inches	millimeters
	PETMUL	real		

(continued)

TABLE 5.2 (continued)

Namelist Name	Parameter Name	Type	English Units	Metric Units
(LND3)[b]	(K3)[c]	real	(12 monthly values)	
(LND4)[b]	INFIL	real	inches/hour	millimeters/hour
	INTER	real		
	IRC	real		
	K24L	real		
	KK24	real		
	K24EL	real		
(LND5)[b]	SGW	real	inches	millimeters
	GWS	real		
	KV	real		
	ICS	real	inches	millimeters
	OFS	real	inches	millimeters
	IFS	real	inches	millimeters
	[SNOWPRINT	character]		
SNO1	RADCON	real		
	CCFAC	real		
	SCF	real		
	ELDIF	real	1000 feet	kilometers
	IDNS	real		
	F	real		
SNO2	DGM	real	inches/day	millimeters/day
	WC	real		
	MPACK	real	inches	millimeters
	EVAPSN	real		
	MELEV	real	feet	meters
	TSNOW	real	degrees F	degrees C
SNO3	PACK	real	inches	millimeters
	DEPTH	real	inches	millimeters
SNO4	PETMIN	real	degrees F	degrees C
	PETMAX	real	degrees F	degrees C
	WMUL	real		
	RMUL	real		
	KUGI	integer		
CROP	COVPMO	real		
(MUD1)[d,e]	(TIMTIL)[d]	integer	days (12 values)	days (12 values)
[MUD2]	(YRTIL)[d]	integer	year (12 values)	year (12 values)

(continued)

TABLE 5.2 (continued)

Namelist Name	Parameter Name	Type	English Units	Metric Units
[MUD3]	(SRERTL)[d]	real	tons/acre (12 values)	tonnes/hectare (12 values)
SMDL	JRER	real		
	KRER	real		
	JSER	real		
	KSER	real		
	SRERI	real	tons/acre	tonnes/hectare
	[SCMPAC]	real	per day	per day
	PESTICIDE	character		
	APMODE	character		
	DESORF	character		
[PSTR]	[PSSZ]	real	pounds/acre	kilograms/hectare
	[PSUZ]	real	pounds/acre	kilograms/hectare
	[PSLZ]	real	pounds/acre	kilograms/hectare
	[PSGZ]	real	pounds/acre	kilograms/hectare
[PST1]	(TIMAP)[f]	integer	day	day
[PST2]	(YEARAP)[f]	integer	year	year
[PST3]	(SSTR)[f]	real	pounds/acre	kilograms/hectare
AMDL	CMAX	real	pounds/pound	kilograms/kg
	DD	real	lbs. pesticide/ lbs. soil	kgs. pesticide/ kgs. soil
	K	real		
	N	real		
	NP	real		
[DEGD]	[DDG]	integer	day	day
[DEGY]	[YDG]	integer	year	year
[DEGR]	(KDG)[g]	real	per day	per day

***NUTRIENT PARAMETERS (Table 5.3) ARE INPUT HERE WHEN NUTR=YES ***

Namelist Name	Parameter Name	Type	English Units	Metric Units
[LZTP]	[LZTEMP]	real	degrees F	degrees C
[RETP]	[ASZT]	real		
	[BSZT]	real		
	[AUZT]	real		
	[BUZT]	real		
[DPTH]	(SZDPTH)[e]	real	inches	millimeters
	(UZDPTH)[e]	real	inches	millimeters

(continued)

TABLE 5.2 (continued)

Namelist Name	Parameter Name	Type	English Units	Metric Units
	(BSDZ)[h]	real	pounds/cubic ft	grams/cubic cm
	(BUDZ)[h]	real	pounds/cubic ft	grams/cubic cm
	(BUDZ)[h]	real	pounds/cubic ft	grams/cubic cm
	[UZF]	real		
	[LZF]	real		

[a] [ ] and ( ) have the same meaning as in Table 5.1.

[b] In Version I, the hydrologic namelists and parameters are:
LND1 - UZSN, UZS, LZSN, LZS
LND2 - L, SS, NN, A, K3 EPXM
LND3 - INFIL, INTER, IRC, K24L, KK24, K24EL
LND4 - SGW, GWS, KV, ICS, OFS, IFS

[c] In Version I, K3 is a single annual value.

[d] In Version I, TIMTIL, YRTIL, and SRERTL are contained in namelist MUD1 and can contain up to five values each.

[e] In Version I, namelist DIRT follows the namelist MUD1 and contains parameters SZDPTH, UZDPTH, and BULKD.

[f] In Version I, TIMAP, YEARAP, and SSTR describe a single pesticide application and are contained in namelist AMDL.

[g] In Version I, a single pesticide degradation rate parameter DEGCON is contained in the namelist DEG1 which follows namelist AMDL.

[h] In Version I, a single soil bulk density parameter, BULKD, replaces BDSZ, BDUZ, and BDLZ, and is contained in the namelist DIRT (note e).

5.2.1 Nutrient Parameter Input Sequence

When NUTR=YES, the block of nutrient parameters follows the DEGR namelist if both nutrients and pesticides are simulated, or the SMDL namelist if only nutrients are simulated. Reference to Table 5.3 and the sample parameter input sequences in Appendix A is important to understanding the nutrient input sequence.

The sequence begins with the title word NUTRIENTS (in column 1) and is followed by the nutrient namelist statements (NUTRIN, PLANTU, PLANTL). Except for the soil namelist statements (LZTP, RETP, DPTH, in Table 5.2), the remaining input of nutrient parameters is done under format control. Also, character strings are input and checked by the program to verify the accuracy of the input sequence. The section begins with the character string REACTION RATES and then the words NITROGEN or PHOSPHORUS to indicate which rates are being input. First order reaction rates may be input for both nitrogen and phosphorus chemical and biological transformations. Separate rates are allowed for the four soil zones; SURFACE, UPPER, LOWER, and GROUNDWATER.

Following the character string NITROGEN, the word SURFACE appears on the next line; then eight reaction rates are listed in F8.0 format on the following line. These reaction rates refer to the various nitrogen forms described in Table 5.3. Following the surface rates, the word UPPER appears in column 1, and the reaction rates for the upper zone are input on the next line. Lower zone and groundwater rates follow in a similar manner. The words TEMPERATURE COEFFICIENTS appear after the groundwater rates and the following line contains the eight constants used for correcting the corresponding reaction rates for nonoptimal temperatures.

Phosphorus reaction rates and temperature coefficients are input in a similar manner except that there are only five reaction rates appearing in an F8.0 format (Appendix A). The word END terminates input of reaction rates. Specifying nitrogen or phosphorus rates is optional, and if values are not given, the program will default the rates to 0.0.

The next section of nutrient input specifies the initial nitrogen, phosphorus, and chloride concentration present in the four soil layers. The word INITIAL begins this section; title words are used in the manner described above. The seven different nitrogen forms, four phosphorus forms and chloride may be initialized as described in Table 5.3. Nutrient concentration is input by soil layer. If initial values are not given for the nitrogen, phosphorus, or chloride forms, the program defaults them to 0.0. The character string END terminates the initialization section.

The final section of the nutrient input sequence indicates the date and amount of application of nutrients during the simulation period. Each nutrient application begins with the word APPLICATION followed by the Julian day of application (for example, 136 in Table A3). The words following indicate which constituents are to be applied: NITROGEN, PHOSPHORUS, or CHLORIDE. Below the constituent type, the application amounts are entered for each form for the surface and upper zone only. The character string END

TABLE 5.3 ARM MODEL (VERSION I AND II) NUTRIENT PARAMETER INPUT SEQUENCE AND ATTRIBUTES[a]

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
NUTRIENT			Character	1-8			Name to indicate start of nutrient input sequence.
	&NUTRIN		Character	2-8			Namelist name of nutrient control information.
		TSTEP	Integer	Any	minutes	minutes	Length of timestep for chemical and biological transformations. There must be an even number of time steps in a day, and an even number of simulation intervals in a TSTEP. Range = 5 or 15 to 1440.
		NAPPL	Integer	Any			Number of nutrient applications over a year of simulation. Values may range from 0 to 5.
		TIMHAR	Integer	Any	day	day	Time of plant harvesting, Julian day of the year. Value may range from 0 to 366.
		&END	Character	Any			Indicate end of namelist statement
	[&PLANTU]		Character	2-8			Namelist name for upper layers plant uptake informations.
		[ULPTK]	Real	Any			12 values of fraction of maximum monthly crop uptake of nutrients, should be 1.0 or less.
		&END	Character	Any			Indicate end of namelist statement
	[&PLANTL]		Character	2-8			Namelist name for lower zone plant uptake information.
		[LZUPTK]	Real	Any			12 values of fraction of maximum monthly crop uptake should be 1.0 or less.
		&END	Character	Any			Indicate end of namelist statement
REACTION RATES			Character	1-14			Name to indicate start of nutrient input sequence.
	NITROGEN		Character	1-8			Indicates nitrogen reaction rate will follow.
	SURFACE		Character	1-7			Surface layer reaction rates follow.
		(K1)[b]	Real	1-8	per day	per day	Oxidation rate of solution ammonium to nitrite and nitrate.
		(KD)[b]	Real	9-16	per day	per day	Reduction rate of nitrite and nitrate to gaseous nitrogen.
		(KPL)[b]	Real	17-24	per day	per day	Uptake of nitrate by plants.

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		KAM	Real	25-32	per day	per day	Ammonification or mineralization rate of organic-N to ammonium.
		KIM	Real	33-40	per day	per day	Immobilization rate of solution ammonium to organic-N.
		KKIM	Real	41-48	per day	per day	Immobilization rate of nitrate and nitrite to organic-N.
		KSA	Real	49-56	per day	per day	Transfer rate of ammonium from solution to adsorbed (adsorption).
		KAS	Real	57-64	per day	per day	Transfer rate of ammonium from adsorbed to solution (desorption).
	UPPER ZONE		Character	1-10			Upper zone reaction rates follow.
		(K1)[b]	Real	1-8	per day	per day	Oxidation rate of solution ammonium to nitrite and nitrate.
		(KD)[b]	Real	9-16	per day	per day	Reduction rate of nitrite and nitrate to gaseous nitrogen.
		(KPL)[b]	Real	17-24	per day	per day	Uptake of nitrate by plants.
		KAM	Real	25-32	per day	per day	Ammonification or mineralization rate of organic-N to ammonium.
		KIM	Real	33-40	per day	per day	Immobilization rate of solution ammonium to organic-N.
		KKIM	Real	41-48	per day	per day	Immobilization rate of nitrate and nitrite to organic-N.
		KSA	Real	49-56	per day	per day	Transfer rate of ammonium from solution to adsorbed (adsorption).
		KAS	Real	57-64	per day	per day	Transfer rate of ammonium from adsorbed to solution (desorption).
	LOWER ZONE		Character	1-10			Lower zone reaction rates folow.
		(K1)[b]	Real	1-8	per day	per day	Oxidation rate of solution ammonium to nitrite and nitrate.
		(KD)[b]	Real	9-16	per day	per day	Reduction rate of nitrite and nitrate to gaseous nitrogen.
		(KPL)[b]	Real	17-24	per day	per day	Uptake of nitrate by plants.
		KAM	Real	25-32	per day	per day	Ammonification or mineralization rate of organic-N to ammonium.
		KIM	Real	33-40	per day	per day	Immobilization rate of dissolved ammonium to organic-N.
		KKIM	Real	41-48	per day	per day	Immobilization rate of nitrate and nitrite to organic-N.
		KSA	Real	49-56	per day	per day	Transfer rate of ammonium from solution to adsorbed (adsorption).

(Continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		KAS	Real	57-64	per day	per day	Transfer rate of ammonium from adsorbed to solution (desorption).
	GROUNDWATER		Character	1-11			Groundwater reaction rates follow.
		(K1)^{b}	Real	1-8	per day	per day	Oxidation rate of solution ammonium to nitrite and nitrate.
		(KD)^{b}	Real	9-16	per day	per day	Reduction rate of nitrite and nitrate to gaseous nitrogen.
		(KPL)^{b}	Real	17-24	per day	per day	Uptake of nitrate by plants.
		KAM	Real	25-32	per day	per day	Ammonification or mineralization rate of organic-N to ammonium.
		KIM	Real	33-40	per day	per day	Immobilization rate of solution ammonium to organic-N.
		KKIM	Real	41-48	per day	per day	Immobilization rate of nitrate and nitrite to organic-N.
		KSA	Real	49-56	per day	per day	Transfer rate of ammonium from solution to adsorbed (adsorption).
		KAS	Real	57-64	per day	per day	Transfer rate of ammonium from adsorbed to solution (desorption).
	TEMPERATURE COEFFICIENTS		Character	1-23			Temperature coefficients for reaction rates.
		(THK1)^{c}	Real	1-8	per day	per day	
		(THKD)^{c}	Real	9-16	per day	per day	
		THKPL	Real	17-24	per day	per day	
		THKAM	Real	25-32	per day	per day	Temperature coefficients for corresponding nitrogen reactions, should be greater than or equal to 1.0.
		THKIM	Real	33-40	per day	per day	
		THKKIM	Real	41-48	per day	per day	
		THKSA	Real	49-56	per day	per day	
		THKAS	Real	57-64	per day	per day	
	PHOSPHORUS		Character	1-10			Indicates phosphorus reaction rates will follow.
	SURFACE		Character	1-7			Surface layer reaction rates.

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to solution phosphate
		KIM	Real	9-16	per day	per day	Immobilization rate of solution phosphate to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate in solution. by plants.
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	UPPER ZONE		Character	1-10			Upper zone reaction rates follow.
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to solution phosphate.
		KIM	Real	9-16	per day	per day	Immobilization rate of solution phosphate to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate in solution. by plants.
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	LOWER ZONE		Character	1-10			Lower zone reaction rates follow.
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to solution phosphate.
		KIM	Real	9-16	per day	per day	Immobilization rate of dissolved PO4-P to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate in solution by plants.
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	GROUNDWATER		Character	1-11			Lower zone reaction rates follow.
		KM	Real	1-8	per day	per day	Mineralization rate of Organic-P to solution phosphate.

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		KIM	Real	9-16	per day	per day	Immobilization rate of solution phosphate to Organic-P.
		KPL	Real	17-24	per day	per day	Uptake of phosphate in solution by plants
		KSA	Real	25-32	per day	per day	Transfer rate of phosphate from solution to adsorbed.
		KAS	Real	33-40	per day	per day	Transfer rate of phosphate from adsorbed to solution.
	TEMPERATURE COEFFICIENTS		Character	1-23			Temperature coefficients for reaction rates.
		THKM	Real	1-8	per day	per day	
		THKIM	Real	9-16	per day	per day	Temperature coefficients for phosphorus reactions, should be greater than or equal to 1.0.
		THKPL	Real	17-24	per day	per day	
		THKSA	Real	25-32	per day	per day	
		THKAS	Real	33-40	per day	per day	
END			Character	1-3			'END' terminates input of rates. Nitrogen and phosphorus rates are optional, program defaults them to 0.0 if not specified.
INITIAL			Character	1-7			Initialization of soil constituents follows.
	NITROGEN		Character	1-8			Initial nitrogen forms follow.
	SURFACE		Character	1-7			Surface layer initialization follows.
		NBLK	Integer	16			Number of blocks which will be input. 0 or 1 indicate the average concentration over the surface layer in input on one line, and NBLK=5 means five lines of input follow, one line per block. Only 0,1,5 allowed. A blank in col. 16 is read as 0.

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable or total organic nitrogen.
		NH4-S	Real	9-16	lb/ac	kg/ha	Ammonium in solution
		NH4-A	Real	17-24	lb/ac	kg/ha	Ammonium adsorbed to soil.
		(NO2 + NO3)[d]	Real	25-32	lb/ac	kg/ha	Nitrite and nitrate
		N2	Real	33-40	lb/ac	kg/ha	Gaseous nitrogen from denitrification.
		PLNT-N	Real	41-48	lb/ac	kg/ha	Plant nitrogen
	UPPER ZONE		Character	1-10			Upper zone initialization follows.
		NBLK	Integer	16			Number of blocks which will be input. 0 or 1 indicate the average concentration over the surface layer in input on one line, and NBLK=5 means five lines of input follow, one line per block. Only 0,1,5 allowed. A blank in col. 16 is read as 0.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable or total organic nitrogen.
		NH4-S	Real	9-16	lb/ac	kg/ha	Ammonium in solution
		NH4-A	Real	17-24	lb/ac	kg/ha	Ammonium adsorbed to soil.
		(NO2 + NO3)[d]	Real	25-32	lb/ac	kg/ha	Nitrite and nitrate
		N2	Real	33-40	lb/ac	kg/ha	Gaseous nitrogen from denitrification.
		PLNT-N	Real	41-48	lb/ac	kg/ha	Plant nitrogen
	LOWER ZONE		Character	1-10			Lower zone initialization.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable or total organic nitrogen.
		NH4-S	Real	9-16	lb/ac	kg/ha	Ammonium in solution

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		NH4-A	Real	17-24	lb/ac	kg/ha	Ammonium adsorbed to soil.
		(NO2 + NO3)[d]	Real	25-32	lb/ac	kg/ha	Nitrite and nitrate
		N2	Real	33-40	lb/ac	kg/ha	Gaseous nitrogen from denitrification.
		PLNT-N	Real	41-48	lb/ac	kg/ha	Plant nitrogen
	GROUNDWATER		Character	1-11			Groundwater zone initialization.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable or total organic nitrogen.
		NH4-S	Real	9-16	lb/ac	kg/ha	Ammonium in solution
		NH4-A	Real	17-24	lb/ac	kg/ha	Ammonium adsorbed to soil.
		(NO2 + NO3)[d]	Real	25-32	lb/ac	kg/ha	Nitrite and nitrate.
		N2	Real	33-40	lb/ac	kg/ha	Gaseous nitrogen from denitrification.
		PLNT-N	Real	41-48	lb/ac	kg/ha	Plant nitrogen
	PHOSPHORUS		Character	1-10			Initial phosphorus forms follow.
	SURFACE		Character	1-7			Surface layer.
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		PO4-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		PO4-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed or combined.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	UPPER ZONE		Character	1-10			Upper zone phosphorus initialization.
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		P04-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		P04-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed or combined.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	LOWER ZONE		Character	1-10			Lower zone initialization.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		P04-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		P04-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed to soil.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	GROUNDWATER		Character	1-11			Groundwater initialization.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		P04-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		P04-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed or combined.
APPLICATION			Character	1&11			Name to indicate start.of nutrient application section, expected number of applications is greater than 0.
		APDAY	Integer	14-18			Application day of the year (Julian Day).
	NITROGEN		Character	1-8			Nitrogen applications follow.
	SURFACE		Character	1-7			Surface applications follow.
		NBLK	Integer	16			Number of blocks which will be input, 0 or 1 indicate one line follows containing the average application over the watershed. A 5 indicates five lines follow, one line for each block.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable or total organic nitrogen applied.

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
		NH4-S	Real	9-16	lb/ac	kg/ha	Ammonium in solution.
		NH4-A	Real	17-24	lb/ac	kg/ha	Ammonium adsorbed to soil.
		(NO2 + NO3)[d]	Real	25-32	lb/ac	kg/ha	Nitrite and Nitrate
		N2	Real	33-40	lb/ac	kg/ha	Gaseous nitrogen from denitrification
		PLNT-N	Real	41-48	lb/ac	kg/ha	Plant nitrogen
	UPPER ZONE		Character	1-10			Upper zone applications follow
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-N	Real	1-8	lb/ac	kg/ha	Potentially mineralizable or total organic nitrogen applied.
		NH4-S	Real	9-16	lb/ac	kg/ha	Ammonium in solution.
		NH4-A	Real	17-24	lb/ac	kg/ha	Ammonium adsorbed to soil.
		(NO2+NO3)[d]	Real	25-32	lb/ac	kg/ha	Nitrite and nitrate
		N2	Real	33-40	lb/ac	kg/ha	Gaseous nitrogen from denitrification.
		PLNT-N	Real	41-48	lb/ac	kg/ha	Plant nitrogen.
							Note: nutrients can only be applied to surface and upper zone.
	PHOSPHORUS		Character	1-10			Phosphorus applications follow.
	SURFACE		Character	1-7			Surface layer application
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		PO4-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		PLNT-P	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed or combined.

(continued)

Table 5.3 (continued)

Block	Section & Subsection	Name	Type	Column Position	Units English	Units Metric	Comments
	UPPER ZONE		Character	1-10			Upper zone application.
		NBLK	Integer	16			Number of blocks which will be input.
		ORG-P	Real	1-8	lb/ac	kg/ha	Organic phosphorus.
		PO4-S	Real	9-16	lb/ac	kg/ha	Phosphate in solution.
		PO4-A	Real	17-24	lb/ac	kg/ha	Phosphate adsorbed or combined.
		PLNT-P	Real	25-32	lb/ac	kg/ha	Plant phosphorus.
	CHLORIDE		Character	1-8			Chloride applications follow.
	SURFACE		Character	1-7			Surface layer application.
		NBLK	Integer	16			Number of blocks which will be input.
		CL	Real	1-8	lb/ac	kg/ha	Chloride applied.
	UPPER ZONE		Character	1-10			Upper zone applications.
		NBLK	Integer	16			Number of blocks which will be input.
		CL	Real	1-8	lb/ac	kg/ha	Chloride applied.
END			Character	1-3	lb/ac	kg/ha	"END" terminates input of applications for that day. NOTE: Nitrogen, phosphorus and chloride do not need to be specified in input sequence if none are applied that day. Program defaults all applications to 0.0.

[a] [ ] and ( ) have the same meaning as in Table 5.1.

[b] In Version I, the K2 (oxidation of NO_2 to NO_3) and KK2 (reduction to NO_3 to NO_2) reaction rates are input after the K1 rate. In Version II, these transformations have been eliminated with a resulting modification to the meaning of the K1, KD, and KPL rates (see Table 5.1).

[c] In Version I, THK2 and THKK2 follow THK1. See note b.

[d] In Version I, separate values for NO2 and NO3 follow the value for NH4-A.

terminates the input of each separate nutrient application. For multiple applications, the sequence is repeated with the character string APPLICATION and the Julian day of application. Applications must be sequential with the first one applied in the year appearing first in the input sequence. The application section is followed by the soil namelist statements (LZTP, RETP, DPTH) shown in Table 5.2. This completes the nutrient parameter input sequence.

5.3 PARAMETER EVALUATION GUIDELINES

Guidelines for evaluating the ARM Model parameters relating to hydrology, snowmelt, sediment, pesticide, and nutrient simulation are provided below. The simulation control parameters are described by their definition in Table 5.1 and discussed in Section 5.1.1. Also, guidelines are provided below for obtaining initial values of the calibration parameters. However, precise evaluation of these parameters can only be obtained through calibration procedures discussed in Section 6.

5.3.1 Hydrology Parameters

A — A is the fraction representing the impervious area in the watershed. Usually A will be negligible for agricultural watersheds, except in cases of extensive rock outcrops along channel reaches.

HYMIN — HYMIN is a control parameter representing the minimum flow above which storm output is printed, and should be chosen to include the significant portion of the storm hydrograph and pollutant graph. Investigation of recorded storm hydrographs and pollutant graphs will indicate an appropriate value of HYMIN. Also, a large value for HYMIN will prevent printing of storm output during calibration runs.

EPXM — This interception storage parameter is a function of cover density, and represents the maximum interception attained during the year. The following values are expected:

grassland	0.10 in.	2.5 mm
cropland (maximum canopy)	0.10-0.25 in.	2.5-6.5 mm
forest cover (light)	0.15 in.	3.5 mm
forest cover (heavy)	0.20 in.	5.0 mm

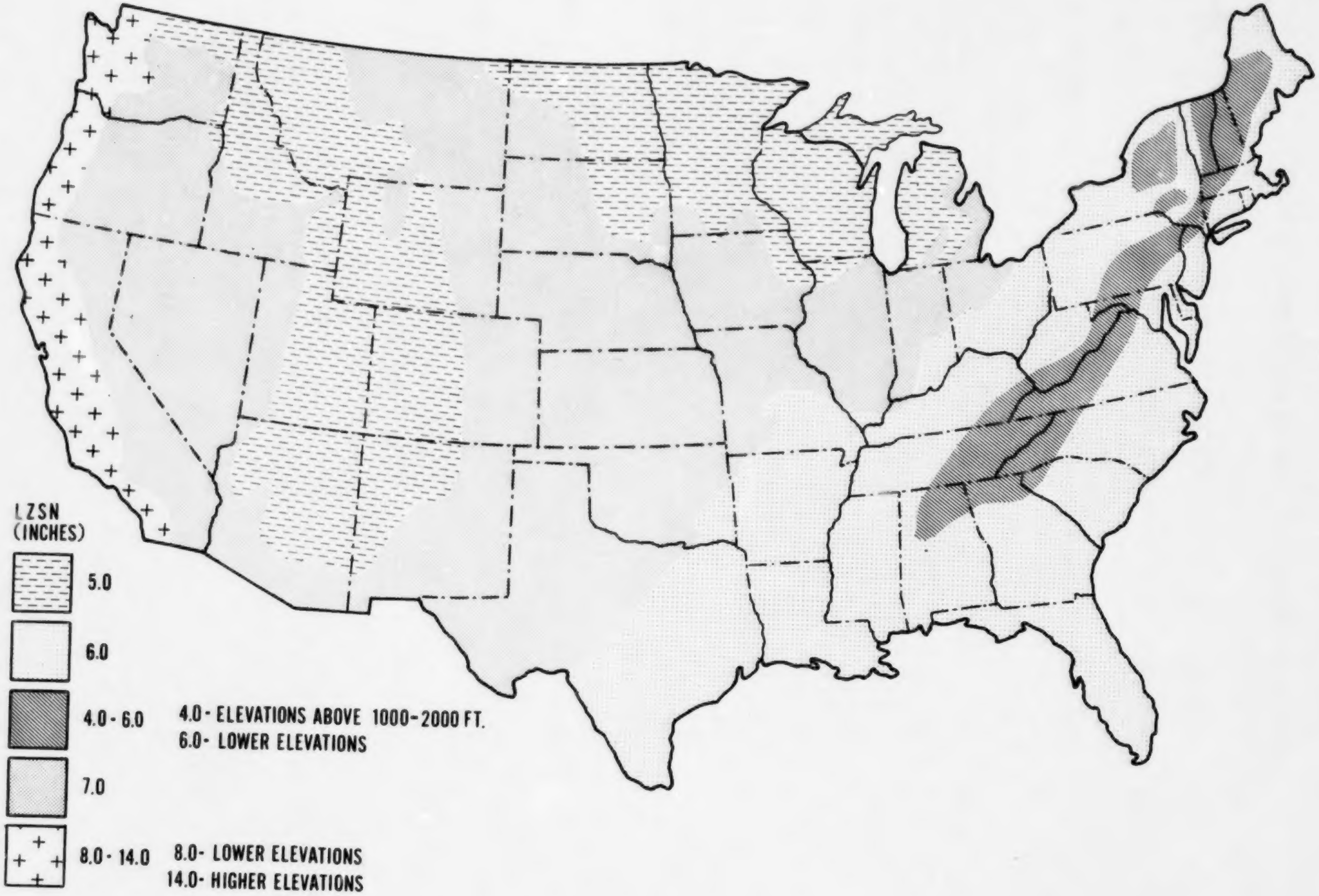
The effective interception on any day is calculated in the model as a function of crop canopy. It is equal to EPXM times the fraction of maximum canopy on that day:

$$\text{Interception (Day T)} = \text{EPXM} * \frac{\text{Canopy (Day T)}}{\text{Maximum Canopy}}$$

UZSN — The nominal storage in the upper zone is generally related to LZSN and watershed topography. However, agriculturally managed watersheds may deviate significantly from the following guidelines:

low depression storage, steep slopes, limited vegetation	0.06*LZSN
moderate depression storage slopes and vegetation	0.08*LZSN
high depression storage, soil fissures, flat slopes, heavy vegetation	0.14*LZSN

LZSN	The nominal lower zone soil moisture storage parameter is related to the annual cycle of rainfall and evapotranspiration. Approximate values range from 5.0 to 20.0 in. (125 to 500 mm) for most of the continental United States depending on soil properties. Figure 5.1 presents an approximate mapping of LZSN values for the United States. This map was obtained by overlaying climatic, topographic, physiographic, and soils information with LZSN values for watersheds calibrated with various versions of the Stanford Watershed Model hydrologic algorithms. The watershed locations are shown in Figure 5.2 and listed in Table 5.4 with various watershed characteristics and calibrated parameter values. Since Figure 5.2 shows that many areas of the country have few calibrated watersheds, Figure 5.1 and Table 5.4 should be used with caution. Initial values of LZSN can be obtained from this information, but the proper value will need to be checked by calibration.
K3	As an index to actual evapotranspiration, K3 affects evapotranspiration from the lower soil moisture zone. The area covered by forest or deep rooted vegetation as a fraction of total watershed area is an estimate of K3. Values generally range from 0.25 for open land and grassland to 0.7-0.9 for heavy forest. Version II of the ARM Model accepts 12 monthly values of K3 to better represent the seasonal variations of actively transpiring vegetation on agricultural cropland.
K24L, K24EL	These parameters control the loss of water from near surface or active groundwater storage to deep percolation and transpiration, respectively. K24L is the fraction of the groundwater recharge that percolates to deep groundwater table. Thus a value of 1.0 for K24L would preclude any groundwater contribution to streamflow and is used on small watersheds without a base flow component from groundwater. K24EL is the fraction of watershed area where shallow water tables put groundwater within reach of vegetation.
INFIL	This parameter is an index to the mean infiltration rate on the watershed and is generally a function of soil characteristics. INFIL can range from 0.01 to 1.0 in./hr


LZSN
(INCHES)
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4.0 - ELEVATIONS ABOVE 1000-2000 FT.
6.0 - LOWER ELEVATIONS
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8.0 - 14.0
8.0 - LOWER ELEVATIONS
14.0 - HIGHER ELEVATIONS

Figure 5.1 Nominal lower zone soil moisture (LZSN) parameter map

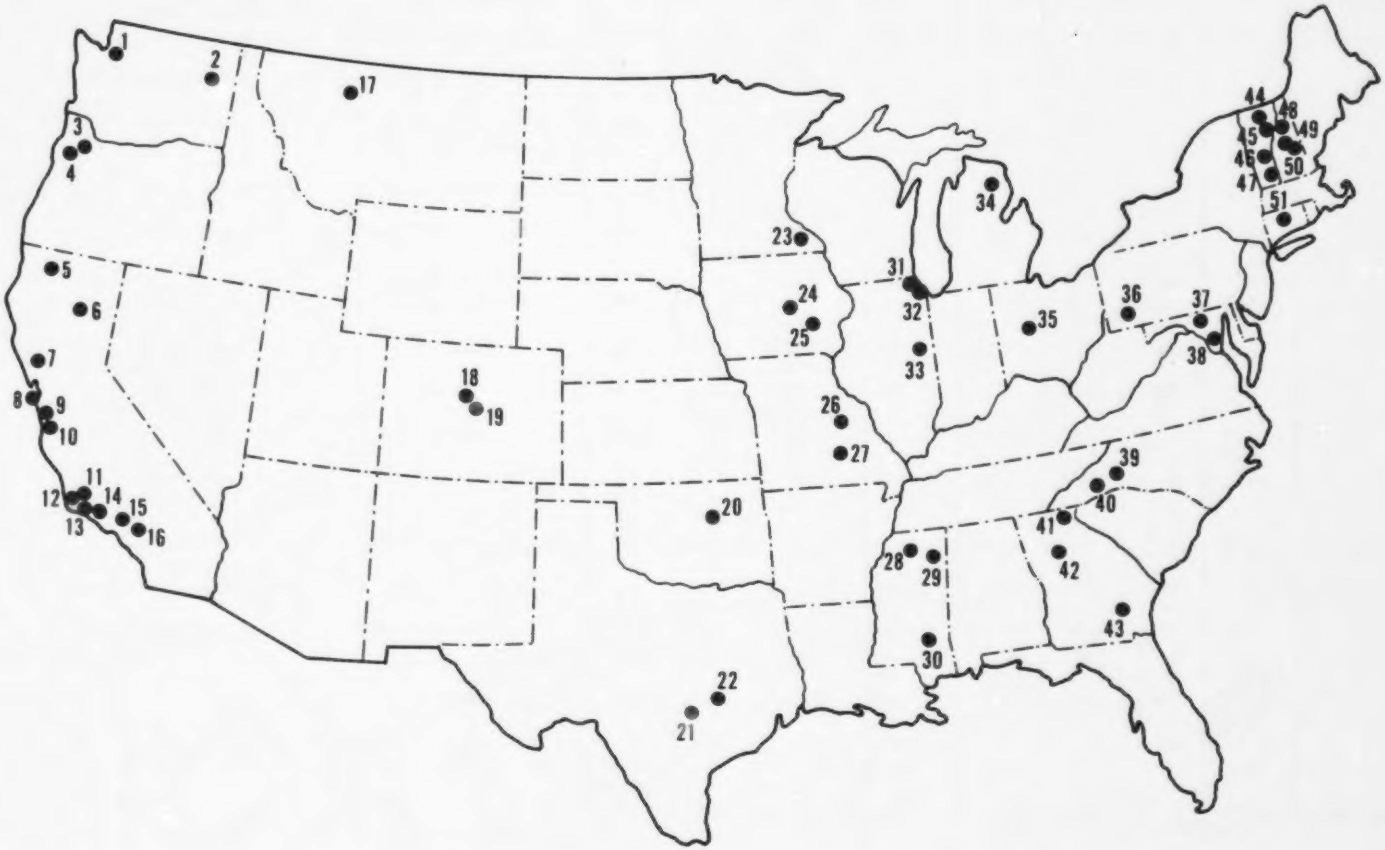
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Figure 5.2 Watershed locations for calibrated LANDS parameters

TABLE 5.4 WATERSHEDS WITH CALIBRATED LANDS PARAMETERS

Watershed Information			Area (sq mi)	Type	LANDS Parameters					
No.	General Location	Name			Model	UZSN	LZSN	INFIL	INTER	Comments
1	Seattle, Washington	Lower Green R			HSP	3.0	12.0	0.06	10.0	
		Middle Green R			HSP	1.15	9.5	0.10	3.0	
		Upper Green R			HSP	0.9	14.0	0.05	11.5	
		Lake Washington			HSP	0.5	8.0	0.05	10.0	
2	Spokane, WA	Little Spokane R		plains, rural	HSP	0.56	7.0	0.20	15	
3	Aschoft, Oregon	Bull Run	107	rural, steep forest	HSP	0.75	14.0	0.08	3.5	
4	Whiteson, Oregon	South Yamhill R	502		NWS	1.20	5.3	0.24	0.5	POWER=0.37
5	Central Sierra Snowlab, CA	Upper Castle Creek	3.96	rural, rocky forest	NWS	0.70	9.0	0.08	0.67	POWER=1.5
6	Between Chico and Flemming, CA	N Fork Feather R	300	rural, steep forest	HSP	0.8	12.0	0.12	2.5	
7	Cloverdale, CA	Dry Creek	878	rural, moderate slope, chaparral	SWM V	0.8	15.0	0.03	1.8	
	Napa, CA	Dry Creek	14.4	rural, moderate slope, chaparral	HSP	0.8	12.0	0.025	2.5	
8	Burlingame, CA	Colma Creek	10.8	urban, moderate slopes	HSP	0.25	12.0	0.07	2.0	
9	Santa Cruz, CA	Branciforte Creek	17.3	rural	HSP	1.0	16.0	0.04	2.5	
10	San Mateo Co, CA	Denniston Creek	3.6	rural, steep chaparral	SWM IV	0.95	12.7	1.35	2.0	
11	Santa Ynez, CA	Sisquoc River	281	rural, steep light chaparral	HSP	0.7	8.5	0.18	1.5	
12	Santa Maria, CA	Santa Maria River	2.38	urban, flat slopes	HSP	0.3	5.0	0.02	1.4	
13	Goleta, CA	San Jose Creek	5.5	rural, steep	HSP	0.5	10.0	0.03	3.5	
14	Santa Ynez, CA	Santa Ynez River	895	rural, steep	HSP	0.74	8.3	0.035	1.5	
15	Los Angeles, CA	Echo Park	0.4	urban, steep residential	HSP	0.04	5.0	0.03	0	
16	Pasadena, CA	Arroyo Seco	16	urban, steep	HSP	0.20	7.0	0.05	1.2	
17	Upper Columbia Snowlab, MT	Skyland Creek	8.1	rural, steep	NWS	1.83	10.7	0.071	5.6	POWER=0.83
18	Denver, CO	South Platte R		rural, moderate slope, grasses	HSP	0.1	0.7	0.03	1.0	
19	30 mi. south of Denver, CO	Cherry Creek	69	rural, moderate	HSP	0.8	7.0	0.005	3.0	

(continued)

TABLE 5.4 (continued)

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Watershed Information			Area (sq mi)	Type	LANDS Parameters					
No.	General Location	Name			Model	UZSN	LZSN	INFIL	INTER	Comments
				slope, grassland						
20	Sperry, OK	Bird Creek	905		NWS	1.38	10.0	0.048	0.67	POWER=0.78
21	Austin, TX	Waller Creek	6.5	urban, moderate	HSP	1.0	8.0	0.04	1.25	
22	Bryon, TX	Burton Creek	1.3	urban, flat	HSP	0.3	5.0	0.02	1.5	
23	Lannesboro, MN	Root River	625		NWS	0.2	5.0	0.08	0.5	POWER=2.0
24	Rock Rapids, IA	Rock River	788		NWS	0.75	4.0	0.02	1.4	POWER=2.5
25	Iowa City, IA	Rapid Creek	25.3		HSP	0.5	7.0	0.035	3.5	
26	St. James, MO	Bourbeuse River	21.3		HSP	0.75	5.0	0.02	1.0	
27	Steelville, MO	Meramec River	781		NWS	1.2	12.7	0.043	1.05	POWER=1.56
28										
29	Nettleton, MO	Town Creek	617		NWS	0.44	7.35	0.066	0.89	POWER=2.6
30	Collins, MI	Leaf River	752		NWS	0.05	7.5	0.33	0.37	POWER=2.85
31	Chicago, IL	North Branch, Chicago River	100	urban, flat,	HSP	1.4	7.5	0.18	3.5	
32	Northbrook, IL	W Fork N Branch Chicago River	11.5	rural	HSP	1.40	7.5	0.18	3.0	
33	Champaign/Urbana, IL	Boneyard Creek	3.6	urban, flat slope	HSP	0.80	7.5	0.05	2.0	
34	Selkirk, MI	S Branch Shepards Creek	1.2		HSP	1.0	5.0	0.04	1.0	
35	Springfield, OH	Mad River	490		NWS	0.41	4.1	0.125	0.83	POWER=0.40
36	Green Lick Reservoir, PA	Green Lick Run	3.1		HSP	1.0	8.0	0.007	1.0	
37	Frederic, MD	Monocacy River	817		NWS	1.2	1.75	0.058	1.0	POWER=0.30
38	E of Washington D.C. in MD	W Branch of Patuxent River	30.2	rural, flat	HSP	1.2	7.0	0.02	2.0	
39	Rosman, NC	French Broad R	67.9	rural, limestone forest	NWS	0.01	5.38	0.8	0.25	POWER=0.36
40	Swannanoa, NC	Beetree Creek	5.5	rural	HSP	0.30	3.0	0.10	30	
41	Blairsville, GA	Nottely River	74.8	rural, forest mountains	NWS	0.02	3.4	0.45	2.5	POWER=2.0
42	Fayetteville, GA	Camp Creek	17.2	urban, hilly forests	NWS	0.5	5.0	0.16	0.75	POWER=2.0
43	Alma, GA	Hurricane Creek	150	rural, forested	NWS	0.2	2.0	0.13	2.6	POWER=2.0
44	Danville, VT	Sleepers River	3.2	rural	NWS	0.25	4.55	0.40	0.25	POWER=3.0
45	Passumpic, VT	Passumpsic River	436	rural	NWS	0.15	5.0	0.33	0.9	POWER=3.0

(continued)

TABLE 5.4 (continued)

Watershed Information					LANDS Parameters					
No.	General Location	Name	Area (sq mi)	Type	Model	UZSN	LZSN	INFIL	INTER	Comments
46	West Hartford, VT	White River	690	rural	NWS	0.25	5.0	0.15	1.3	POWER=0.95
47	Grafton, VT	Saxton River	72.2		SWM V	0.8	8.0	0.05	2.0	
48	Bath, NH	Ammonoosuc River	395	rural	NWS	0.3	5.0	0.12	0.65	POWER=1.50
50	Plymouth, NH	Pemigewasset River	622	rural	NWS	0.25	5.0	0.22	0.53	POWER=2.08
51	Knightsville Dam, MA	Sykes Brook	1.6		HSP	1.2	8.0	0.03	1.0	
others										
52	Fairbanks, AK	Chena River	1980		NWS	0.05	5.0	0.08	0.25	POWER=1.0
53	Seattle, WA	Issaquah Creek	55	rural, steep heavy forest	HSP	1.12	14.0	0.03	7.0	
54	Spokane, WA	Hangman Creek	54	agriculture	HSP	0.50	7.0	0.02	3.5	
55	Santa Cruz, CA	Neary's Lagoon	1.0	urban, steep	HSP	0.80	11.0	0.04	2.5	
56	Ingham, Co. MI	Deer Creek	16.3	rural, flat agriculture	HSP	1.5	5.0	0.05	2.0	
57	Athens, GA	Southern Piedmont	0.01	small plot watersheds	PTR	0.05	18.0	0.5	0.7	
				RANGES		0.01-3.0	1.75-18	.005-1.35	11.5-25	

a. HSP Hydrocomp Simulation Program
SWM IV Stanford Watershed Model IV
SWM V Stanford Watershed Model V
NWS National Weather Service Model
PTR Pesticide Transport and Runoff Model

b. HSP and the SWM Models use a value of 2.0 in the infiltration function while the NWS Model allows the user to specify this value with the POWER parameter. The values of POWER are indicated in the comments column.

depending on the cohesiveness and permeability of the soil. Initial values for INFIL can be obtained by reference to the hydrologic soil groups of the Soil Conservation Service (1974) in the following manner:

SCS Hydrologic Soil Group	INFIL Estimate (in./hr)	INFIL Estimate (mm/hr)	Runoff Potential
A	0.4-1.0	10.0-25.0	low
B	0.1-0.4	2.5-10.0	moderate
C	0.05-0.1	1.25-2.5	moderate to high
D	0.01-0.05	.25-1.25	high

The SCS has specified the hydrologic soil group for various soil classifications across the country (1974). As for LZSN, the values of INFIL obtained above should be used with caution and only as initial values to be checked by calibration.

INTER This parameter refers to the interflow component of runoff and generally alters runoff timing. It is closely related to INFIL and LZSN and values generally range from 0.5 to 5.0. Figure 5.3 provides an approximate mapping of the INTER parameter for the United States. This map was obtained as described for the LZSN parameter. In addition, INTER values in Table 5.4 provide an indication of representative values. This information should be used only to obtain initial values that need to be checked by calibration.

L L is the length of overland flow obtained from topographic maps and approximates the length of travel to a stream channel. Its value can be approximated by dividing the watershed area by twice the length of the drainage path or channel. Values usually range from 100 ft (30 meters) to 300 ft (90 meters) since overland flow rapidly forms into drainage ditches.

SS SS is the average overland flow slope obtained from topographic maps. The average slope can be estimated by superimposing a grid pattern on the watershed, estimating the land slope at each point of the grid, and obtaining the average of all values measured.

NN Manning's n for overland flow will vary considerably from published channel values because of the extremely small depths of overland flow. Approximate values are:

smooth, packed surface	0.05
normal roads and parking lots	0.10
disturbed land surfaces	0.15

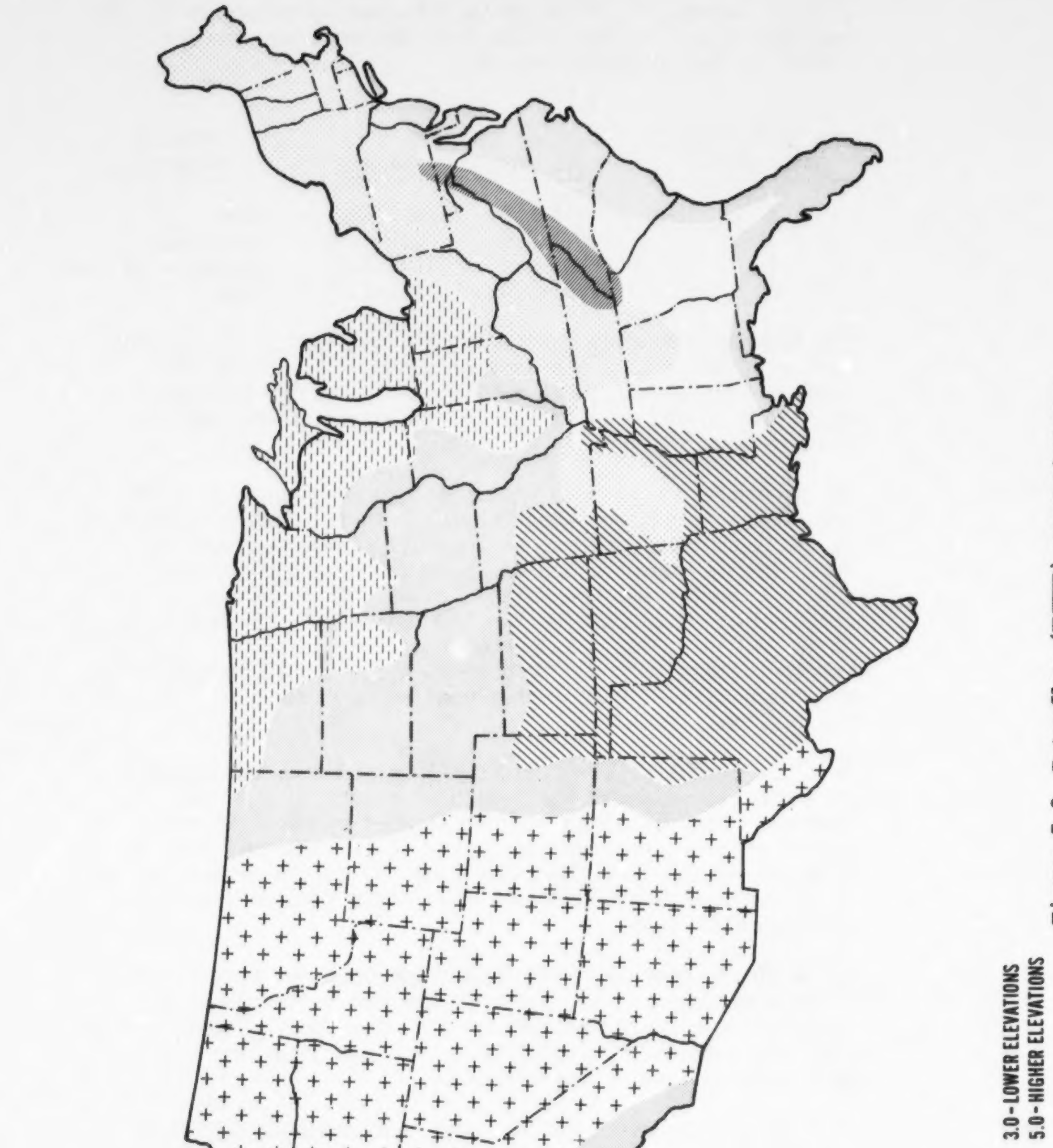

NTERFLOW
0.75
1.0
1.5
2.0
2.5
3.0
3.0-5.0
3.0-LOWER ELEVATIONS
5.0-HIGHER ELEVATIONS

Figure 5.3 Interflow (INTER) parameter map

turf	0.25
heavy turf and forest litter	0.35

PETMUL

PETMUL is a multiplier that adjusts the input potential evapotranspiration data to expected conditions on the watershed. Values near 1.0 are used if the input data has been collected on or near the watershed to be simulated.

IRC, KK24

These parameters are the interflow and groundwater recession rates. They can be estimated graphically by hydrograph separation techniques (Linsley, et al. 1975), or found by trial from simulation runs. Since these parameters are defined below on a daily basis, they are generally close to 0.0 for small watersheds that only experience runoff during or immediately following storm events.

$$\text{IRC} = \frac{\text{Interflow discharge on any day}}{\text{Interflow discharge 24 hours earlier}}$$

$$\text{KK24} = \frac{\text{Groundwater discharge on any day}}{\text{Groundwater discharge on 24 hours earlier}}$$

KV, GWS

The parameter KV is used in conjunction with the groundwater slope index, GWS, to allow a variable recession rate for groundwater discharge. If KV = 1.0 the effective recession rate for different levels of KK24 and the variable GWS is:

	GWS			
KK24	0.0	0.5	1.0	2.0
0.99	0.99	0.985	0.98	0.97
0.98	0.98	0.97	0.96	0.94
0.97	0.97	0.955	0.94	0.91
0.96	0.96	0.94	0.92	0.88

GWS is higher during wet periods when groundwater is being recharged and lower during dry periods. Thus KV affects the seasonal distribution of groundwater flow; increasing KV will increase baseflow during wet periods and decrease it during dry periods with no significant effect on the total baseflow volume.

For small watersheds without a groundwater flow component, a value of 0.0 is generally used for both KV and the initial value of GWS.

UZS, LZS, SGW

These parameters are the initial soil moisture conditions for the upper zone, lower zone, and groundwater zone, respectively at the beginning of the simulation period. SGW is the component of groundwater storage that contributes to streamflow. It is usually set to 0.0 for initial calibration runs. The factor (1.0-K24L) specifies the fraction of the total groundwater component added to SGW, while the outflow from active groundwater is determined by the recession rate, KK24. UZS and LZS are generally specified relateive to their nominal storages, UZSN and LZSN. If simulation begins in a dry period, UZS and LZS should be less than their nominal values; whereas values greater than nominal should be employed if simulation begins in a wet period of the year. UZS, LZS, and SGW should be reset after a few calibration runs according to the guidelines provided in Section 6.

5.3.2 Snow Parameters

RADCON, CCFAC	These parameters adjust the theoretical melt equations for solar radiation and condensation/convection melt to actual field conditions. Values near 1.0 are to be expected although past experience indicates a range of 0.5 to 2.0. RADCON is sensitive to watershed slopes and exposure, while CCFAC is a function of climatic conditions.
SCF	The snow correction factor is used to compensate for catch deficiency in rain gages when precipitation occurs as snow. Precipitation times the value of (SCF-1.0) is the added catch. Values are generally greater than 1.0 and usually are in the range of 1.0 to 1.5.
ELDIF	This parameter is the elevation difference from the temperature station to the mean elevation in the watershed in thousands of feet (or kilometers). It is used to correct the observed air temperatures for the watershed using a lapse rate of 3° F per 1,000 ft elevation change (5.5°C per 1,000 m).
IDNS	This parameter is the density of new snow at 0° F. The expected values are from 0.10 to 0.20 with 0.15 a common value. The relationship for the variation in snow density with temperature is described by Donigian and Crawford (1976a).
F	This parameter is the fraction of the watershed that has complete forest cover. Areal photographs are the best basis for estimates.
DGM	DGM is the daily groundmelt. Values of 0.01 in/day (0.25 mm/day) are usual. Areas with deep frost penetration may have little groundmelt with DGM values approaching 0.0.
WC	This parameter is the maximum water content of the snowpack by weight. Experimental values range from 0.01 to 0.05 with 0.03 a common value.

MPACK	MPACK is the estimated water equivalent of the snowpack for complete areal coverage in a watershed. Values of 1.0 to 6.0 in. (25 to 150 mm) are generally employed. MPACK is a function of topography and climatic conditions. Mountainous watersheds will generally have MPACK values near the high end of the range.
EVAPSN	EVAPSN adjusts the amounts of snow evaporation given by an analytic equation. Values near 0.1 are expected.
MELEV	The mean elevation of the watershed in feet (meters).
TSNOW	Wet bulb air temperature below which snow is assumed to occur. Values of 31° to 33° F (-0.6 to + 0.6° C) are often used. Comparing the recorded form of precipitation and the simulated form for a number of years will indicate needed modifications to TSNOW.
PETMIN, PETMAX	These parameters allow a reduction in potential evapotranspiration for air temperatures near or below 32° F (0° C). PETMIN specifies the air temperature below which potential evapotranspiration is zero. For air temperature between PETMIN and PETMAX, potential evapotranspiration is reduced by 50 percent while no reduction is performed for temperatures above PETMAX. Values of 35° F (1.7° C) and 40° F (4.4° C) have been used for PETMIN and PETMAX, respectively.
WMUL, RMUL	These parameters are multipliers used to adjust input wind movement and solar radiation, respectively, for expected conditions on the watershed. Values of 1.0 are used if the input meteorologic data are observed on or near the watershed to be simulated.
KUGI	KUGI is an integer index to forest density and undergrowth for the reduction of wind in forested areas. Values range from 0 to 10; for KUGI = 0, wind in the forested area is 35 percent of the input wind value, and for KUGI = 10 the corresponding value is 5 percent. For medium undergrowth and forest density, a KUGI value of 5 is generally used.

5.3.3 Sediment Parameters

JRER	JRER is the exponent in the soil splash equation of the sediment algorithm; it approximates the relationship between rainfall intensity and incident energy to the land surface for the production of soil fines. Wischmeier and Smith (1958) have proposed the following relationship for the kinetic energy produced by natural rainfall;

$$Y = 916 + 331 \log X$$

where Y = kinetic energy, ft/tons per acre/in.
X = rainfall intensity, in./hr

Using this relationship, various investigations have also shown that soil splash is proportional to the square of the rainfall intensity (Meyer and Wischmeier 1969, David and Beer 1974). Thus, a value of about 2.0 for JRER is predicted from these studies. In general, values in the range of 2.0 to 3.0 have demonstrated reasonable results on the limited number of watersheds tested. The best value will need to be checked through calibration.

KRER This parameter is the coefficient of the soil splash equation and is related to the erodibility or detachability of the specific soil type and land surface conditions. Presently, limited experience indicates that KRER is directly related to the K and P factors in the Universal Soil Loss Equation (Wischmeier and Smith 1965) and can be initially estimated as KRER = K*P. K values can be obtained with techniques published in the literature or from soil scientists familiar with local soil conditions. Table 5.5 provides a list of the expected magnitudes of K values for various soil types, and Figure 5.4 is a nomograph for general estimation of K from soil properties. Other available information on K factors for the specific watershed should be consulted. Table 5.6 provides values of P for various practices affecting land surface conditions. The user should note that the practices listed in Table 5.6 also affect other ARM Model parameters, such as NN, UZSN, L, and SS. The impact of different agricultural practices can only be evaluated with changes in all relevant parameters.

The initial value of KRER will need to be checked through calibration trials.

JSER JSER is the exponent in the sediment washoff or transport equation and thus approximates the relationship between overland flow intensity and sediment transport capacity. Values in the range of 1.0 to 2.5 have been used on the limited number of watersheds tested to date. The most common values are between 1.6 and 2.0, but initial values should be checked through calibration.

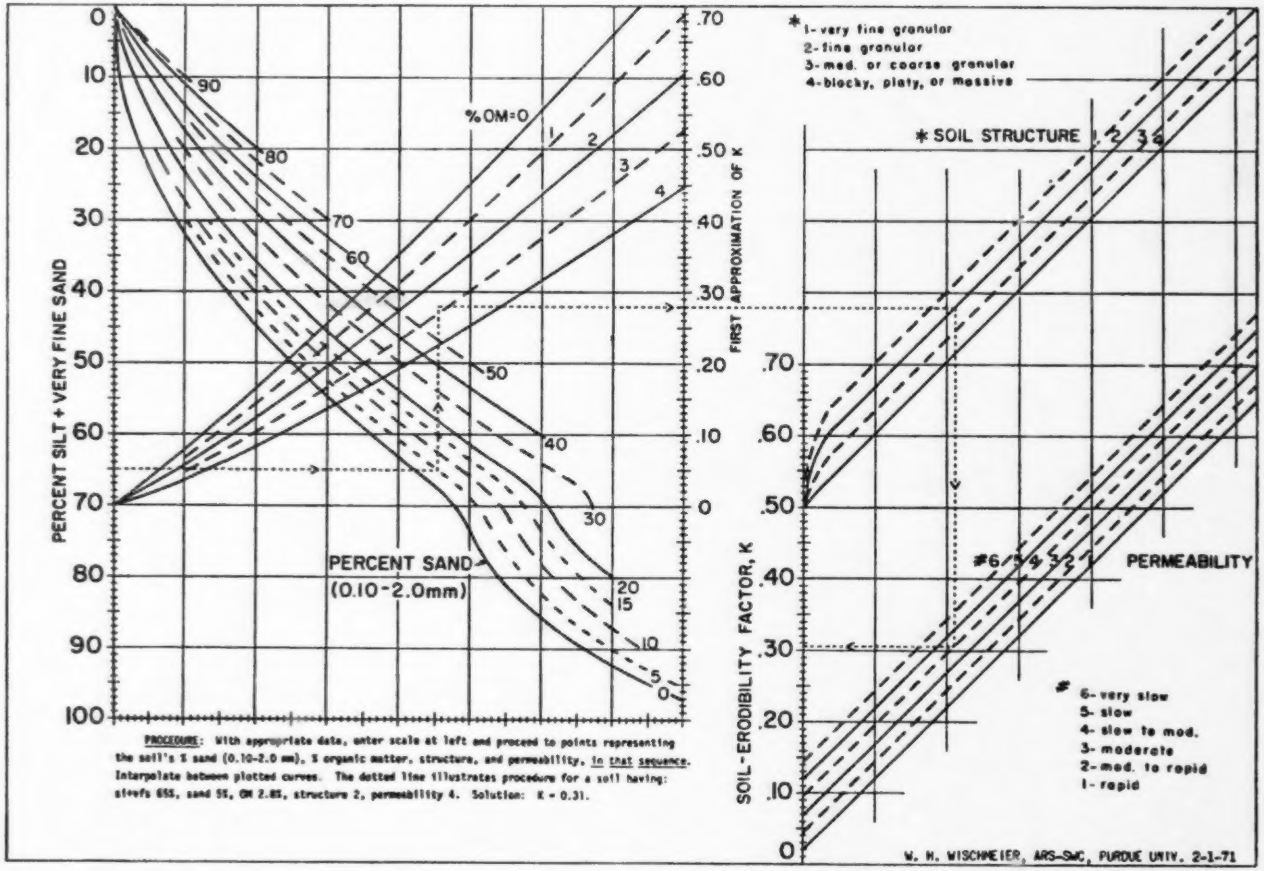
KSER KSER is the coefficient in the sediment washoff, or transport, equation. It is an attempt to combine the effects of (1) slope, (2) overland flow length, (3) sediment particle size, and (4) surface roughness on sediment transport capacity of overland flow into a single calibration parameter. Consequently, at the present time calibration is the major method of evaluating KSER. Terracing, tillage practices, and other agricultural management techniques will have a significant effect on KSER. Limited experience to

TABLE 5.5 INDICATIONS OF THE GENERAL MAGNITUDE OF THE SOIL-ERODIBILITY FACTOR, K[1]

		Organic matter content	
Texture class	<0.5%	2%	4%
	K	K	K
Sand	.05	.03	0.02
Fine sand	.16	.14	.10
Very fine sand	.42	.36	.28
Loamy sand	.12	.10	.08
Loamy fine sand	.24	.20	.16
Loamy very fine sand	.44	.38	.30
Sandy loam	.27	.24	.19
Fine sandy loam	.35	.30	.24
Loamy very fine sand	.44	.38	.30
Loam	.38	.34	.29
Silt loam	.48	.42	.33
Silt	.60	.52	.42
Sandy clay loam	.27	.25	.21
Clay loam	.28	.25	.21
Silty clay loam	.37	.32	.26
Sandy clay	.14	.13	.12
Silty clay	.25	.23	.19
Clay		0.13-0.29	

[1] The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values. For specific soils, use of Figure 5.4 or Soil Conservation Service K-value tables will provide much greater accuracy.

Source: Stewart, et al. 1975.



PROCEDURE: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0 mm), % organic matter, structure, and permeability, in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: si+vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

Figure 5.4 Soil erodibility nomograph

Source: Wischmeier, Johnson, and Cross (1971), p. 190

TABEL 5.6 VALUES OF SUPPORT-PRACTICE FACTOR, P

Practice	Land Slope (percent)				
	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
			Factor P		
Contouring (P_c)	0.60	0.50	0.60	0.80	0.90
Contour strip cropping (P_{sc})					
R-R-M-M[1]	0.30	0.25	0.30	0.40	0.45
R-W-M-M-	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.70
R-O	0.60	0.50	0.60	0.80	0.90
Countour listing or ridge planting (P_{cl})	0.30	0.25	0.30	0.40	0.45
Contour terracing (P_t)[2, 3]	$0.6/\sqrt{n}$	$0.5/\sqrt{n}$	$0.6/\sqrt{n}$	$0.8/\sqrt{n}$	$0.9/\sqrt{n}$
No support practice	1.0	1.0	1.0	1.0	1.0

[1] R = rowcrop, W = fall-seeded grain, O = spring-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that rowcrop strips are always separated by a meadow or winter-grain strip.

[2] These P_t values estimate the amount of soil eroded to the terrace channels and are used for conservation planning. For prediction of off-field sediment, the P_t values are multiplied by 0.2.

[3] n = number of approximately equal-length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Source: Stewart, et al. 1975.

date has indicated a possible range of values of 0.01 to 5.0. However, significant variations from this can be expected.

SRERI, SRERTL

These parameters indicate the amount of detached soil fines on the land surface at the beginning of the simulation period (SRERI) and the amount produced by tillage operations (SRERTL). Very little research or experience relates to the estimation of these parameters. Thus, calibration is the method of evaluation. For SRERI, one would expect that spring and summer periods on agricultural watersheds would require higher values than fall and winter periods due to the growing season disturbances and activities on the watershed. Values of SRERTL are related to the severity or depth of the tillage operation, and must be input to correspond with the dates of tillage operations (TIMTIL, YRTIL). Values of these parameters on the limited number of calibrated watersheds have ranged from 0.5 to 2.0 tons/acre (1.0 to 4.5 t/ha).

COVPMO

This parameter is the fraction land cover on the watershed and is used to decrease the fraction of the land surface that is susceptible to soil fines detachment by raindrop impact. Twelve monthly values for the first day of each month are input to the model, and the cover on any day is determined by linear interpolation. Overhead photographs at periodic intervals during the year are the most direct means of estimating the fraction land cover.

COVPMO values can be estimated as one minus the C factor in the Universal Soil Loss Equation, i.e. COVPMO = 1 - C, when C is a monthly value. For cropland, the C factors for the various stages of crop growth should be used in estimating COVPMO.

Tables 5.7 and 5.8 pertain to the evaluation of C on undisturbed lands and have been reproduced from the paper by Wischmeier (1975). C factors for disturbed lands (croplands, agriculture, and construction areas) have been published in the USLE Report (Wischmeier and Smith 1965). The COVPMO values estimated from C may need to be reduced since the C factor includes considerations other than crop canopy and raindrop interception.

SCMPAC

SCMPAC is a soil compaction factor that reduces the amount of detached soil particles available for transport. It is a first-order decrease (per day) of the surface storage of soil fines performed on a daily basis during nonstorm periods. The SCMPAC parameter attempts to represent the natural aggregation and mutual attraction of soil particles and the compaction of the surface soil zone from which erosion occurs. These processes are a complex function of soil characteristics, meteorologic conditions, and tillage

TABLE 5.7 C VALUES FOR PERMANENT PASTURE, RANGELAND, AND IDLE LAND[a]

Canopy		Ground cover						
Type and height[b] (1)	Pct cover[c] (2)	Type[d] (3)	Pct cover					
			0 (4)	20 (5)	40 (6)	60 (7)	80 (8)	95–100 (9)
None	...	G	0.45	0.20	0.10	0.042	0.012	0.003
		W	.45	.24	.15	.091	.043	.011
Weeds or short brush (0.5 m).	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Brush or bushes (2 m).	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, no low brush (4 m).	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.013	.003
		W	.36	.20	.13	.084	.041	.011

[a] All values assume (1) random distribution of mulch or vegetation, and (2) mulch of substantial depth where credited.

[b] Classified by average fall height of waterdrops from canopy to soil surface, in meters.

[c] Percentage of total-area surface that would be hidden from view by canopy in a vertical projection.

[d] G—Cover at surface is grass or decaying, compacted duff of substantial depth. W—Cover at surface is weeds (plants with little lateral-root network near the surface) or undecayed residue.

TABLE 5.8 C FACTORS FOR WOODLAND

Stand condition	Tree canopy (pct of area)[a]	Forest litter (pct of area)[b]	Undergrowth[c]	C-Factor
Well stocked	100–75	100–90	Managed[d]	0.001
			Unmanaged	.003–0.011
Medium stocked	75–40	90–75	Managed	.002– .004
			Unmanaged	.01– .04
Poorly stocked	40–20	70–40	Managed	.003– .009
			Unmanaged	.02– .09[e]

[a] Area with tree canopy over less than 20 pct will be considered grassland or cropland for estimating soil loss (table 2).

[b] Forest litter is assumed to be of substantial depth over the percent of the area on which it is credited.

[c] Undergrowth is defined as shrubs, weeds, grasses, vines, etc. on the surface area not protected by forest litter. Usually found under canopy openings.

[d] Managed—Grazing and fires are controlled. Unmanaged—Stands that are overgrazed or subjected to repeated burning.

[e] For unmanaged woodland with litter cover of less than 75 pct, C-values should be derived by taking 0.7 of the appropriate values in table 2. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

Source: Wischmeier (1975), pp. 123-24.

practices for which a detailed simulation is not possible at present. Values in the range of .001 to .1 are possible.

5.3.4 Soil Parameters

LZTEMP

This parameter is an array of the average monthly soil temperatures of the lower and groundwater zones. Values may be estimated from nearby soil temperatures given by the Environmental Data Service or from groundwater temperatures published in U.S. Geological Survey Water Data publications.

ASZT, BSZT, AVZT, BUZT

These parameters are regression constants which relate air temperature (AT) to surface soil temperature (STEMP) and the upper zone soil temperature (UTEMP) to STEMP as follows:

$$STEMP = ASZT + BSZT*AT$$
$$UTEMP = AUZT + BUZT*STEMP$$

They must be determined by correlating air temperatures and soil temperatures for the simulation period. The ARM Model calculates hourly air temperatures with a sinusoidal interpolation between the input max-min air temperatures, assuming the minimum temperature occurs between 5 a.m. and 6 a.m. and the maximum occurs between 3 p.m. and 4 p.m. Thus, the regression equations are used on an hourly basis, but the constants can be developed from max-min or daily air and soil temperature data.

SZDPTH, UZDPTH

These parameters refer to the depth of the active surface zone (SZDPTH) and the depth from the land surface to the bottom of the upper soil zone (UZDPTH). Although these parameters specify soil depths, their major impact is on the retention and concentration of adsorbed chemicals (pesticides and nutrients) in each zone.

Very little experience exists for evaluation of these depths. SZDPTH is expected to range from 0.06 in. to 0.25 in. (1.5 to 6.0 mm) with a value of 0.12 in. (3 mm) commonly used. Adjustments to SZDPTH will affect the concentration of adsorbed pollutants in surface runoff (Section 6.4).

UZDPTH is generally evaluated as the depth of incorporation of soil-incorporated chemicals. It also indicates the depth used to calculate the mass of soil through which interflow, percolation, and associated chemicals are assumed to pass, whether the chemicals are soil-incorporated or surface applied. UZDPTH is expected to range from 2.0 to 6.0 in. (5.0 to 15.0 cm) with a value of 3.0 in. (7.6 cm) commonly used. UZDPTH must be greater than SZDPTH.

BDSZ, BDUZ, BDLZ	These parameters refer to the soil bulk density in each depth zone: surface (BDSZ), upper zone (BDUZ), and lower zone (BDLZ). These values may be available from some soil surveys, or from agricultural extension personnel when field sampling is not available. Values generally range from 75 to 112 lb/cu ft (1.2 to 1.8 g/cc) and 100 lb/cu ft (1.6 g/cc) is commonly used. Surface soils will normally have lower bulk densities than deeper soils. Likewise, soils with much organic content will have lower bulk densities than those with little organic content.
UZF, LZF	These parameters are the chemical leaching factors for the upper zone (UZF) and lower zone (LZF). They adjust the amount of chemical leached with infiltrating and percolating water. Values between 1.0 and 5.0 have been used for UZF with less chemical leaching with the higher values. Values are related to soil porosity with the lower values used for more porous soils (Donigian, et al. 1977). Calibration of these parameters with the downward movement of tracers, such as chloride, is recommended. Otherwise, these parameters can be adjusted to represent reasonable leaching of soluble chemicals. The LZF has not been studied adequately to determine if a deviation from a value of 1.0 is needed.

5.3.5 Pesticide Parameters

DD, K, N, NP	These parameters define the adsorption/desorption functions used in the ARM Model. DD represents the capacity of the soil to permanently adsorb the applied pesticide so that it will not desorb under repeated washings. Its units are in pounds (kilogram) of pesticide per pound (kilogram) of soil. K and N are the standard Freundlich constants defining the single-valued adsorption/desorption isotherm. The ARM Model reports contain complete descriptions of the adsorption/desorption algorithms and parameters. Ideally the values of these parameters should be determined by laboratory experiments for each specific pesticide-soil combination. Pesticide manufacturers will often have parameter values for their own pesticides on various soils, and the general literature (technical reports and journals) can be consulted for values for the more common pesticides on soils similar to those on the simulation watershed. However, laboratory values may not accurately describe a pesticide behavior under field conditions; they may require some adjustment or calibration (Section 6.4). DD is related to the cation or anion exchange capacity of the soil depending on the chemical properties of the pesticide. The effect of nonzero values of DD is to specify the amount of pesticide that can be applied before

any can be detected in solution in the runoff water. This permanently bound pesticide amount equals the product of DD, the depth of the zone of application (either SZDPTH or UZDPTH), the corresponding bulk density, and the watershed area. For highly ionic pesticides, such as paraquat, the assumption of permanent adsorption is reasonable, but most pesticides will require extremely small values or zero for DD (the DD value used for paraquat on Cecil soils was 0.0003).

K and N values are highly variable and dependent on the specific pesticide-soil combination. The assumption of a linear isotherm would use an N value of 1.0 with K being the partitioning coefficient (the ratio of sediment to solution concentrations).

The NP values used to date have been 2 to 3 times the corresponding N value.

CMAX

CMAX is the water solubility of the pesticide being simulated. Literature values are generally used, no temperature correction is performed, and the input value is dimensionless (i.e. pesticide mass/water mass). Pesticide simulation results appear to be relatively insensitive to CMAX because the solution concentrations have been much less than the input solubility value.

KDG

KDG is the first-order pesticide degradation, or attenuation, rate. Up to 12 values can be input to the ARM Model with each value activated on the day and year specified by the corresponding DDG and YDG parameters, respectively. Thus KDG(1) is activated on day DDG(1) in year YDG(1) and remains in effect until KDG(2) is activated on day DDG(2) in year YDG(2) and so on. In this way, a single degradation rate can be applied for the entire season, or different rates can be applied to different time periods following application. This latter approach is an attempt to use different KDG values for degradation/attenuation processes that predominate at different times following application, as shown in Figure 5.5.

Degradation processes are the major mechanisms determining the amount of pesticide available for transport from the watershed throughout the growing season. Thus accurate representation of these processes is critical to simulating pesticide runoff to the aquatic environment. As with the adsorption parameters, KDG values should be determined for the specific pesticide, soil, and environmental conditions of the watershed. Pesticide manufacturers and the technical literature should be consulted if specific degradation rate information is not available. Menzie (1972) has reported the estimated half-life of many pesticides

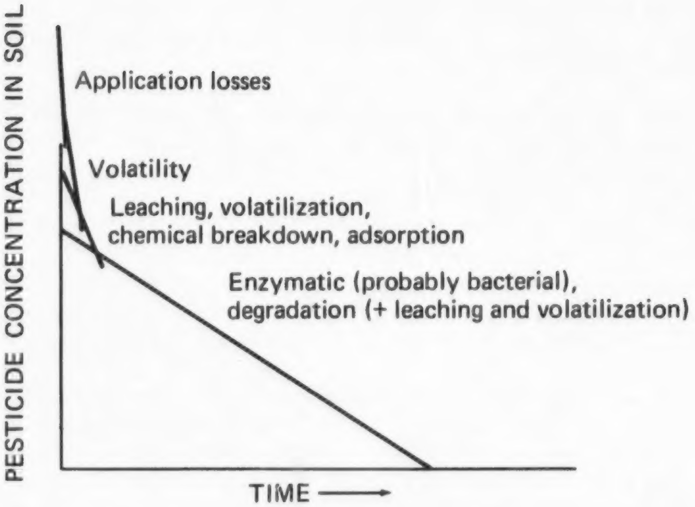


Figure 5.5 Theoretical degradation curve for soil applied pesticides (Edwards 1964)

in soils, and Stewart, et al. (1975) have tabulated the approximate persistence in soil (that is, time required for 90 percent or more degradation) for 60 agricultural herbicides. These values reproduced in Table 5.9 can be converted to daily degradation rates for input to the ARM Model as follows:

$$KDG = \begin{cases} 2.3/t_{90} \\ \text{or} \\ 0.693/t_{50} \end{cases}$$

where t_{90} and t_{50} are the time period, in days, for 90 percent and 50 percent degradation, respectively, of the applied pesticide. Literature values may need to be adjusted or calibrated to field conditions if pesticide soil data are available (Section 6.4).

5.3.6 Nutrient Parameters

The nutrient model has been applied to the P2 watershed in Watkinsville, Georgia and the P6 watershed in East Lansing, Michigan. The nutrient reaction rates and temperature adjustment coefficients for these watersheds are listed in Table 5.10 as general information for nutrient parameter evaluation. Note that reaction rates are input for each soil zone and that a value of 0.0 will eliminate a particular transformation (as shown in Figure 2.5) and can be used to prevent reactions from being simulated in any zone. Thus the groundwater reaction rates in Table 5.10 are 0.0 because transformations in groundwater were not important to the simulation.

TSTEP	This parameter designates the time step in minutes for the chemical and biological nutrient transformations. Values range from 5- or 15- to 1440-min (1 day). There must be an even number of time steps in one day and an even number of simulation intervals in a TSTEP. Most testing of the model has been with a 60-min time step. At time steps much larger than 60-min, the solution technique may be less accurate. A warning message will be printed if the time step is too large for the solution technique.
NAPPL	NAPPL is the number of nutrient applications. Application information must be repeated NAPPL times following the initial storage values in the input sequence. Nutrient applications may be designated for fertilizer or for crop residue remaining or incorporated after harvesting.
TIMHAR	This parameter designates the time of crop harvesting at which the plant nutrient storages in the model are reset to zero. The amount of nutrients harvested is printed in the monthly summary. Typically, other ARM parameters referring to crop canopy, uptake, and evapotranspiration should be adjusted for the harvesting period.

TABLE 5.9 PERSISTENCE OF AGRICULTURAL CHEMICALS IN SOILS

(Menzie 1972)

Pesticide	Approximate Half-Life in Soil	Pesticide	Approximate Half-Life in Soil
DDT	3-10 years	Chlorthion	36 days
Aldrin	1-4 years	DDVP	17 days
Dieldrin	1-7 years	Dipterex[a]	140 days
Isodrin/endrin	4-8 years	Disyston	290 days
Heptachlor	7-12 years	Demeton S	54 days
Chlordane	2-4 years	Methyl demeton S	26 days
Toxaphene	10 years	Dursban[a]	29-1930 days
BHC	2 years	Diazinon	6-184 days
Parathion, ethyl	180 days	Chlorfenvinphos	14-161 days
Parathion, methyl	45 days	Dimethoate	122 days
Thimet[a]	2 days		

(Stewart, et al. 1975)

Common Names of Herbicides	Approximate Persistence[b] in Soil, days	Common Names of Herbicides	Approximate Persistence[b] in Soil, days
Alachlor	40-70	Fenac[a]	350-700
Ametryne[a]	30-90	Fenuron	30-270
Amitrole	15-30	Glyphosate	150
Asulam	25-40	Isopropalin	150
Atrazine	300-500	Linuron	120
Barban	20	MCPA	30-180
Benefin	120-150	Metribuzin	150-200
Bensulide	500-700	Molinate	80
Bifenox	40-60	Monuron	150-350
Bromacil	700	Naptalam	20-60
Butylate	40-80	Paraquat	500
CDAA	20-40	Pebulate[a]	50-60
CDEC	20-40	Phenmedipham	100
Chloramben	40-60	Picloram	550
Chloroxuron	300-400	Profluralin	320-640
Chlorpropham	120-260	Prometone[a]	400
Cycloate[a]	120-220	Prometryne[a]	30-90
2,4-D Acid	10-30	Pronamide[a]	60-270
2,4-D Amine	10-30	Propachlor[a]	30-50
2,4-D Ester	10-30	Propanil[a]	1-3
Dalapon	15-30	Propazine[a]	200-400
DCPA	400	Propham	20-60
Diallate	120	Pyrazon	30-60
Dichlobenil	60-180	Simazine	200-400
Dinitramine	90-120	TCA	20-70
Dinoseb	15-30	Terbacil	700
Diphenamid	90-180	Terbutryne[a]	20-70
Diquat	500	Triallate[a]	30-40
Diuron	200-500	Trifluralin	120-180
EPTC	30	Vernolate[a]	50

[a] Trade name; no corresponding common name exists.
[b] Persistence refers to time required for 90 percent degradation

TABLE 5.10 NUTRIENT REACTION RATES AND TEMPERATURE COEFFICIENTS USED FOR THE P2 AND P6 WATERSHED

P2 WATERSHED—Watkinsville, Georgia

Nitrogen Rates (day^{-1})	K1	KD	KPL	KAM	KIM	KKIM	KSA	KAS
Surface	1.000	.0000	.1000	.0000	.0000	.0000	1.0000	.2000
Upper Zone	.20000	.0060	.1300	.0020	.0000	.0000	1.0000	.2500
Lower Zone	.1000	.0020	.0250	.0020	.0000	.0000	1.0000	.2000
Groundwater	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Temperature Coef.	1.050	1.070	1.070	1.070	1.070	1.070	1.050	1.050

Phosphorus Rates (day^{-1})	KM	KIM	KPL	KSA	KAS
Surface	.0200	.0000	.0100	1.0000	.0150
Upper Zone	.0020	.0000	.7000	1.0000	.0015
Lower Zone	.0020	.0000	.8000	1.0000	.0050
Groundwater	.0000	.0000	.0000	.0000	.0000
Temperature Coef.	1.070	1.070	1.070	1.050	1.050

P6 WATERSHED—E. Lansing, Michigan

Nitrogen Rates (day^{-1})	K1	KD	KPL	KAM	KIM	KKIM	KSA	KAS
Surface	3.000	.0000	.2500	.0150	.0000	.0000	5.0000	.7500
Upper Zone	1.2500	.0500	.4000	.0015	.0000	.0000	.7500	.3000
Lower Zone	.7000	.0000	.0900	.0015	.0000	.0000	1.0000	.4000
Groundwater	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
Temperature Coef.	1.050	1.070	1.070	1.070	1.070	1.070	1.050	1.050

Phosphorus Rates (day^{-1})	KM	KIM	KPL	KSA	KAS
Surface	.0150	.0000	.0100	1.0000	.0100
Upper Zone	.0015	.0000	2.1000	.5000	.0060
Lower Zone	.0015	.0000	1.7000	.5000	.0050
Groundwater	.0000	.0000	.0000	.0000	.0000
Temperature Coef.	1.070	1.070	1.070	1.050	1.050

ULUPTK, LZUPTK	These parameters refer to the combined surface and upper zone layers (ULUPTK) and the lower zone (LZUPTK) crop uptake fractions. They are monthly fractions of the maximum monthly uptake of nitrogen and phosphorus with values less than or equal to 1.0. The month with the highest expected uptake should be set equal to 1.0. This is usually the month with the most crop growth. Some adjustment of these parameters and the uptake rate (KPL) will be needed in order to represent the expected crop uptake pattern. Figure 5.6 shows the expected pattern of growth and uptake for corn.
KPL	KPL is the maximum uptake rate and is input separately for nitrogen and phosphorus. It is used with the above crop uptake fractions to represent the crop uptake pattern from each zone during the growing season. Little information is presently available in the literature on first order reaction rates of crop uptake, so calibration of this parameter may be needed. Adjustment of KPL will often be the major effort in nutrient parameter calibration. Approximate nutrient contents of various crops are given in Table 5.11, and uptake rates should be calibrated to provide the expected pattern and level of total uptake. However, these values will vary with location and environmental conditions. Therefore, a local agricultural specialist should be consulted. Figure 5.6 and similar information for other crops can then be used to estimate the distribution of the plant uptake from the different soil layers during the growing season. Generally 40 percent of the total nutrient uptake of a mature normal crop with roots to a 5-ft depth (for example, corn, sorghum, soybean, and peanuts) is thought to occur from the top foot (30 cm) of soil.
K1	This parameter is the nitrification reaction rate. Oxygen content is a major determinent of this parameter, so the deeper the soil the lower the rate should be. Soils that are saturated much of the time will also have lower rates. Nitrification rates have been in the range of 0.2 and 3.0 per day. The nitrification rate should be calibrated to ammonium and nitrate soil storage data unless laboratory measurements are available.
KD	KD is the dentrification reaction rate. Denitrification rates are larges under anaerobic conditions. However, Broadbent and Clark (1965) estimated 10 to 15 percent of the annual mineral nitrogen input to agricultural areas is lost by denitrification under normal crop conditions. Since the extent of denitrification is dependent upon fluctuating field conditions, the rates should be estimated or calibrated. If the field is under ordinary aerobic conditions, that is, little flooding or stagnant water, the denitrification

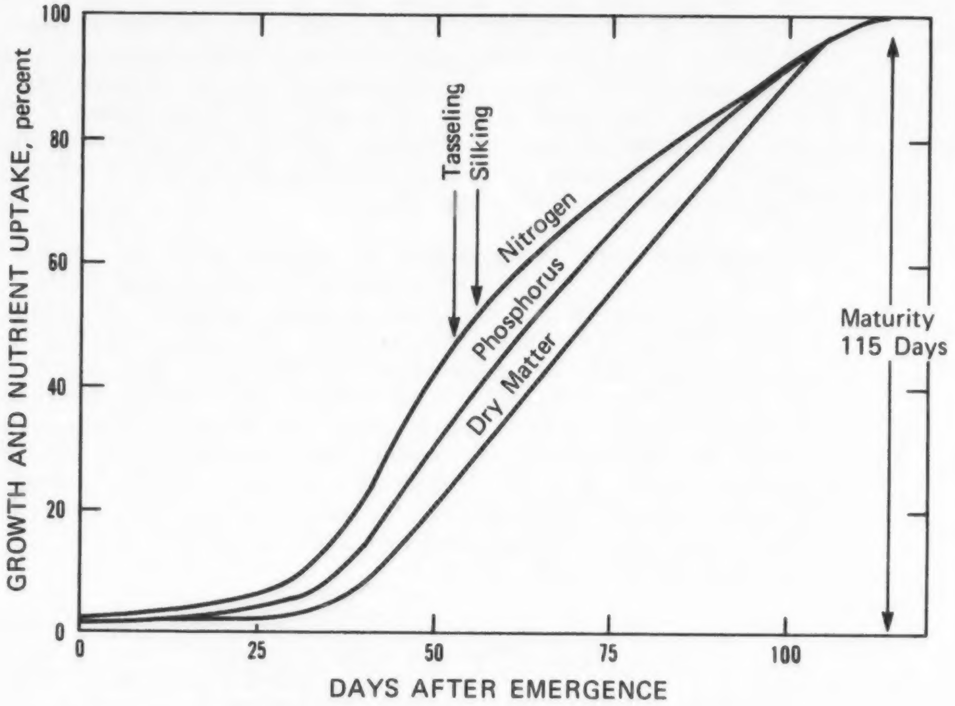


Figure 5.6 Corn growth and nutrient uptake (Steward, et al. 1975).

TABLE 5.11 APPROXIMATE YIELDS AND NUTRIENT CONTENTS OF SELECTED CROPS[a] (Stewart et al 1975)

Crop		Yield/acre	Lbs N/acre	Lbs P/acre[c]
Alfalfa[b]		4 tons	200	18
Apples		500 bu	30	4
Barley	grain	40 bu	35	6
	straw	1 ton	15	2
Beans[b]	(dry)	30 bu	75	10
Bermudagrass		8 tons	200	30
Bluegrass		2 tons	60	8
Cabbage		20 tons	150	16
Clover[b]	red	2 tons	80	10
	white	2 tons	130	10
Corn	grain	150 bu	135	24
	stover	4.5 tons	100	16
	silage	25 tons	200	30
Cotton	lint and seed	1 ton	60	12
	stalks	1 ton	45	6
Cowpea Hay[b]		2 tons	120	10
Lettuce		20 tons	90	12
Lespedeza[b]		2 tons	85	8
Oats	grain	90 bu	55	10
	straw	2 tons	25	8
Onions		7.5 tons	45	8
Oranges		28 tons	85	12
Peaches		600 bu	35	8
Peanuts[b]	nuts	1.5 tons	110	6
Potatoes	tubers	400 cwt	95	12
	vines	1 ton	90	8
Rice	grain	90 bu	55	12
	straw	2.5 tons	30	4
Rye	grain	30 bu	35	4
	straw	1.5 tons	15	4
Sorghum	grain	60 bu	50	10
	stover	3 tons	65	8
Soybean[b]	grain	45 bu	160	16
	straw	1 ton	25	4
Sugarbeets	roots	20 tons	85	14
	tops	12 tons	110	10
Sugar cane	stalks	30 tons	100	20
	tops	13 tons	50	10
Timothy		2.5 tons	60	10
Tobacco		1.5 tons	115	10
Tomatoes	fruit	25 tons	145	20
	vines	1.5 tons	70	10
Wheat	grain	50 bu	65	14
	straw	1.5 tons	20	2

[a] Values can vary by a factor of two across the country (Stewart, et al. 1975)

[b] Legumes that do not require fertilizer nitrogen

[c] lbs P = 0.436 lbs P_2O_5

	reaction rate could be considered as less than 0.001 or 0.0 per day. If there is too much nitrogen in the soil system after other demands have removed nitrogen, a higher value could be used with discretion. When estimating rates from literature values, it must be remembered that the reaction rate used in the model is based on the total nitrite and nitrate content, and not merely the nitrite.
KM, KAM, KIM, KKIM	These parameters refer to the mineralization and immobilization rates of nitrogen (KAM, KIM, KKIM) or phosphorus (KM, KIM). Typical laboratory information refers to net mineralization rates. When using such net rates, immobilization rates (KIM, KKIM) can be set to 0.0. Extensive research has been done by the U.S. Soils Laboratory on net nitrogen mineralization rates. Table 5.12 gives first order rates for mineralizable N and the percentages of total N which is mineralizable N. If total Organic N values are used for initial storages, these rates should be multiplied by the percent of mineralizable N to obtain the corresponding rate. Otherwise, the Organic N values for initial storages should refer to only the mineralizable organic N, and the rates in Table 5.12 can be used directly (with conversion to daily values). According to Stanford and Smith (1972) the most reliable estimate of the net mineralizable N rate was 0.054 + 0.009 week^{-1}. However, the fraction of mineralizable N of total N varied widely, 5 to 40 percent, in this study. Unless other values are available, the net mineralization rate of phosphorus can be assumed to be the same as the nitrogen rate. These rates should not have to be calibrated unless the values in Table 5.12 are considered inapplicable for the specific watershed conditions.
KAS, KSA	These parameters correspond to the adsorption (KSA) and desorption (KAS) rates for nitrogen or phosphorus. These rates are useful in keeping the adsorbed ammonium and phosphate forms in the soil system and not taken up by plants, moved by water, or transformed. The cation exchange capacity will influence the extent of ammonium adsorption, while the amounts of complexing ions (Al, Fe, Ca) as well as pH influence the extent of phosphorus adsorption. Typically, most of the phosphorus is in the adsorbed phase. The extent of adsorption is determined by the proportion of KSA to KAS; the magnitude of the rates determine the actual rate of adsorption and desorption. Little information is available on these rates in the literature, but indications are that complete adsorption of applied compounds occurs within days. Calibration should be performed with observed data unless adsorption isotherms are available.

TABLE 5.12 PAST MANAGEMENT, SURFACE SOIL NITROGEN PROPERTIES, AND NET MINERALIZATION RATE OF MINERALIZABLE N FOR VARIOUS SOILS[a] (Stanford and Smity 1972)

Soil Designation and Location[b]	Previous Management	Total N %[c]	Mineralizable N	
			% of Total N	Net Rate of Mineralization Week^{-1}
	Alfisol			
Amarillo fsl (TX)	Cotton and sorghum	0.053	17.4	0.066 ± .009
Hagerstown sil (PA)	Hay (some alfalfa) with little fertilizer; 145 kg N/ha on corn	0.144	15.2	0.063 ± .012
Grenada fsl (Miss.)	Unlimed; Bermudagrass; avg. N, 245, kg/ha	0.132	27.0	0.042 ± .007
	Limed; Bermuda, avg. N, 245 kg/ha	0.141	25.4	0.056 ± .014
	Old alfalfa field; limed corn, 180 kg N/ha	0.116	27.9	0.062 ± .011
Corfu fsl (WA)	Sagebrush and bunchgrass,	0.043	9.1	0.056 ± .010
	Aridisol			
Minidoka sil (ID)	Wheatgrass and sagebrush	0.128	23.1	0.071 ± .011
Portneuf sil (ID)	Potatoes, 125 kg N/ha/yr	0.104	19.7	0.082 ± .014
Shano sil	Wheat-fallow	0.039	4.6	0.095 ± .031
Warden fsl (WA)	Wheat-fallow presently uncropped and unirrigated	0.040	16.0	0.058 ± .009
	Entisol			
Colby sil (CA)	Wheat-fallow, no fertilizer	0.096	15.4	0.069 ± .011
Regent sicl (ND)	Smooth bromegrass, no fertilizer	0.222	10.4	0.047 ± .008
Ritzville sil (WA)	Wheat-fallow, no fertilizer	0.068	10.0	0.083 ± .003
Sprole sil (MT)	Wheat-fallow, no N or P fertilization	0.145	19.8	0.056 ± .004
Temvik sil (ND)	Small grains, no N fertilizer	0.205	11.7	0.042 ± .003
Walla Walla sil (WA)	Wheat-fallow, 60 kg/N/ha (avg.) on wheat	0.085	12.1	0.047 ± .008
Weld sil	Wheat-fallow, no fertilizer	0.065	21.5	0.045 ± .005
	Ultisol			
Cecil sl (GA)	Corn, no N fertilizer; grass-crimson	0.021	23.8	0.035 ± .009
	Corn, 180 kg N/ha/yr; grass-clover	0.031	27.4	0.076 ± .010
	4-yr rotation of corn (no N) and 3-yrs fescue-clover (80 kg N/ha/yr)	0.051	40.6	0.052 ± .013
	4-yr rotation of corn (180 kg N/ha) and 3-yrs fescue-clover 80 kg N/ha/yr)	0.049	36.1	0.056 ± .012
Goldsboro sl (SC)	Corn, 73 kg N/ha/yr	0.039	11.0	0.068 ± .018
Greenville fsl (AL)	Uncropped, no N recently	0.048	2..0	0.050 ± .012
	General cropping, 225-335 kg N/ha/yr	0.049	17.1	0.054 ± .006
Leck Kill sil (PA)	Barley-meadow; 33 and 42 kg N/ha	0.115	25.7	0.052 ± .010
Norfolk fsl (SC)	Corn; 73 kg N/ha/yr	0.030	13.3	0.056 ± .017
Holtville scl	Sugar beet-barley rotation; manure and 180 kg N/ha on each crop	0.127	24.0	0.052 ± .004
	Sugar beet-barley rotation, 360 and 135 kg N/ha/yr, resp.	0.086	19.0	0.052 ± .004
	Alfalfa-sugar beets-barley; no N fertilizer	0.086	17.7	0.053 ± .004
Lakeland ls (SC)	Corn, no fertilizer	0.031	10.0	0.078 ± .029
Quincy ls (OR)	Uncropped recently irrigated for potato and alfalfa	0.039	29.2	0.087 ± .011
	Mollisol			
Aastad cl (MN)	Corn, no fertilizer	0.211	10.9	0.057 ± .007
Barnes l (MN)	Bromegrass, corn, soybeans, oats, no fertilizer	0.234	13.6	0.057 ± .006
Bearden sil (MN)	Corn, oats, fallow, soybeans, 40 kg N/ha/yr (avg.) on corn, oats	0.190	11.9	0.045 ± .007
Kranzburg sil (SD)	Alfalfa, corn, oats, 90 and 34 kg N/ha on corn and oats	0.231	13.5	0.050 ± .007
Parshall fsl (ND)	Spring wheat, bromegrass no fertilizer	0.112	12.5	0.050 ± .009
Palouse sil (WA)	Winter wheat, dry peas rotation, 84 kg N/ha/yr on wheat	0.135	11.5	0.064 ± .008
Pullman sicl (TX)	Dry farmed; wheat, sorghum, and cotton	0.110	25.7	0.044 ± .008
Rago sil	Wheat-fallow, no fertilizer	0.110	15.4	0.044 ± .006

[a] Refer to original paper for more detail.
[b] f = fine, s = sand, Si = silt, c = clay, l = loam
[c] Total N percent is from surface soils sampled to plow depth (15-20 cm)

Temperature Coefficients

The temperature coefficients correct the input reaction rates for temperatures less than 35° C. Values should not differ extensively from one location to another. Values found in Table 5.10 which were used in prior testing should be used unless other information to the contrary is found. Table 5.13 shows the effect of the temperature coefficient on the input reaction rates.

Nutrient Storages

The nutrient storages should be obtained from analyses of field samples whenever possible. Otherwise, values could be obtained from soil surveys, estimates of prior fertilizer application, or from agricultural extension personnel. Estimates of surface zone sediment associated chemicals can be made from analysis of the composition of eroded material. The nutrient forms measured in the soil should be comparable with those analyzed in the runoff. That is, the same laboratory analysis techniques and measured nutrient forms should be used for the soil core samples and the nutrient content of the runoff.

TABLE 5.13 FRACTIONS OF INPUT REACTION RATES FOR VARIOUS TEMPERATURE COEFFICIENTS (θ)

Soil Temperature		Fraction of Input Reaction Rate		
	θ=1.0	θ=1.05	θ=1.07	θ=1.10
$>35^{\circ}$	1.0	1.0	1.0	1.0
33°	1.0	0.90	0.87	0.83
30°	1.0	0.86	0.71	0.62
25°	1.0	0.61	0.51	0.39
20°	1.0	0.48	0.36	0.24
15°	1.0	0.38	0.29	0.15
10°	1.0	0.30	0.18	0.09
5°	1.0	0.23	0.13	0.06
$< 4^{\circ}$	0	0	0	0

SECTION 6

CALIBRATION PROCEDURES AND GUIDELINES

Calibration has been repeatedly mentioned throughout this user manual; this indicates the importance of the calibration process in application of the ARM Model. At the risk of further repetition, the calibration process will be defined and described in this section and recommended procedures and guidelines will be presented. The goal is to provide a general calibration methodology for potential users of the ARM Model. As one gains experience in calibration, the methodology will become second nature and individual methods and guidelines will evolve.

6.1 ARM MODEL CALIBRATION PROCESS

Calibration is an iterative procedure of parameter evaluation and refinement by comparing simulated and observed values of interest. It is required for parameters that cannot be deterministicly evaluated from topographic, climatic, soil, or physical/chemical characteristics. Fortunately, the large majority of ARM parameters do not fall in this category.

Ideally calibration of the ARM Model will be limited to the hydrologic and sediment parameters to the extent possible. Although the key pesticide and nutrient parameters are quantities measurable in laboratory experiments, we have found that the literature often does not contain the necessary information for the particular pesticides, nutrient forms, soils, crops, and test watershed conditions. Also, laboratory experimental conditions can produce values that may not be applicable to variable field conditions. This is especially true for the nutrient parameters. All efforts should be made to extract the necessary information from the literature. However, when the literature is lacking parameter values for the specific test conditions, extrapolation or adjustment of "similar" literature values is essentially a calibration-type process. The literature values are adjusted to improve the agreement between simulated and recorded values. Thus, some calibration of certain pesticide and nutrient parameters, such as pesticide degradation rates, adsorption constants, and nutrient transformation rates may be necessary when pertinent information is lacking.

Calibration should be based on several years of simulation (3 to 5 yrs is optimal) in order to evaluate parameters under a variety of climatic, soil, and water quality conditions. However, due to lack of data on sediment, pesticide, and nutrients, calibration for these constituents is usually performed on whatever data are available.

The areal variability of meteorologic data series, especially precipitation and air temperature, may cause additional uncertainty in the simulation. Years with heavy precipitation are often better simulated for hydrology because of the relative uniformity of large events over a watershed. In contrast, low annual runoff may be caused by a single or a series of small events that did not have a uniform areal coverage. Parameters calibrated on a dry period of record may not adequately represent the processes occurring during wet periods. Also, the effects of initial conditions of soil moisture and sediment pollutant storages can extend for several months resulting in biased parameter values calibrated on short simulation periods. Calibration should result in parameter values that produce the best overall agreement between simulated and observed values throughout the calibration period.

Calibration includes the comparison of annual, monthly, and storm event values for runoff components (quantity and quality), and soil storage values of pesticide and nutrient content for simulation of soil profile processes. Ideally all these comparisons should be performed for a proper calibration and simulation of hydrologic, sediment, pesticide, and nutrient processes. Hydrologic calibration must preceed sediment calibration which, in turn, preceeds the pesticide and/or nutrient calibration. This is necessary because runoff is the transport mechanism for sediment, and both runoff (and vertical moisture movement) and sediment are the transport mechanisms for pesticides and nutrients. Thus, the major steps in the overall calibration process are:

(1) estimation of all ARM Model parameters, including calibration parameters, from the guidelines provided
(2) hydrologic calibration of annual and monthly runoff volumes
(3) hydrologic calibration of storm events
(4) sediment calibration of annual and monthly sediment loss, and storm events
(5) pesticide/nutrient calibration of soil processes (and soil temperature simulation)
(6) pesticide/nutrient calibration of runoff components

Note that the calibration process is not entirely sequential; that is, some iterative fine tuning of hydrologic and sediment parameters may be required during the pesticide/nutrient calibration to better simulate runoff quality. Pesticide and nutrient calibration are not interdependent; they can be performed in any order following hydrology and sediment calibration. Also, soil temperature simulation is required only for nutrient simulation.

Each of the major calibration categories (hydrology, sediment, pesticides, and nutrients) are described below, along with suggestions and guidelines for parameter adjustment. Although sufficient data may not be available to perform all the comparisons in the calibration process, the user should analyze and evaluate all the simulated information with respect to data from similar watersheds, personal experience, and the guidelines provided.

6.2 HYDROLOGIC CALIBRATION

Hydrologic simulation combines the physical characteristics of the watershed geometry and the observed meteorologic data series to produce the simulated hydrologic response. All watersheds have similar hydrologic components, but they are generally present in different combinations; thus different hydrologic responses occur on individual watersheds. The ARM Model simulates runoff from four components: surface runoff from impervious areas directly connected to the channel network, surface runoff from pervious areas, interflow from pervious areas, and groundwater flow. Since the historic streamflow is not divided into these four units, the relative relationship among these components must be inferred from the examination of many events over several years of continuous simulation. Periods of record with a predominance of one component (for example, surface runoff during storm periods, or groundwater flow after extended dry periods) can be studied to evaluate the simulation of the individual runoff components.

6.2.1 Annual Water Balance

The first task in hydrologic calibration is to establish a water balance on an annual basis. This balance specifies the ultimate destination of incoming precipitation and is indicated as:

$$\text{Precipitation} - \text{Actual Evapotranspiration} - \text{Deep Percolation} - \Delta\text{Soil Moisture Storage} = \text{Runoff}$$

In addition to the input meteorologic data series, the parameters that govern this balance are LZSN, INFIL, and K3 (evapotranspiration index parameter). Thus, if precipitation is measured on the watershed, and if deep percolation to groundwater is small, actual evapotranspiration must be adjusted to cause a change in the long-term runoff component of the water balance. LZSN and INFIL have a major impact on percolation and are important in obtaining an annual water balance. In addition, on extremely small watersheds (less than 100-200 hectares) that contribute runoff only during and immediately following storm events, the UZSN parameter can also affect annual runoff volumes because of its impact on individual storm events (described below).

Recommendations for obtaining an annual water balance are as follows.

(1) Annual precipitation should be greater than or equal to the sum of annual evaporation plus annual runoff if groundwater recharge through deep percolation is not significant in the watershed. If this does not occur, the input precipitation should be re-evaluated and adjusted to insure that it is indicative of that occurring on the watershed.

Since precipitation is highly variable, especially in mountainous and thunderstorm areas, a single gage may not accurately represent the actual precipitation on the watershed. The water balance equation (above) is often used to estimate the actual precipitation needed to produce the observed runoff. The input precipitation values are then adjusted accordingly.

(2) Since the major portion of actual evapotranspiration occurs from the lower soil moisture zone, increasing LZSN will increase actual evapotranspiration and decrease annual runoff. Also, decreasing LZSN will reduce actual evapotranspiration and increase annual runoff. Thus, LZSN is the major parameter for deriving an annual water balance.

(3) The INFIL parameter can also assist in deriving an annual water balance although its main effect is to adjust the seasonal, or monthly runoff distribution described below. Since INFIL governs the division of precipitation into various components, increasing INFIL will decrease surface runoff and increase the transfer of water to lower zone and groundwater. The resulting increase in water in the lower zone will produce higher actual evapotranspiration. Decreasing INFIL will reduce actual evapotranspiration and increase surface runoff. In watersheds with no baseflow component (from groundwater), INFIL can be used in conjuction with LZSN to establish the annual water balance.

6.2.2 Seasonal or Monthly Distribution of Runoff

When an annual water balance is obtained, the seasonal or monthly distribution of runoff can be adjusted with use of the INFIL parameter. INFIL, the infiltration parameter, accomplishes this seasonal distribution by dividing the incoming moisture among surface runoff, interflow, upper zone soil moisture storage, percolation to lower zone soil moisture, and groundwater storage. Of the various hydrologic components, groundwater is often the easiest to identify. In watersheds with a continuous baseflow, or groundwater component, increasing INFIL will reduce immediate surface runoff (including interflow) and increase the groundwater component. In this way, runoff is delayed and occurs later in the season as an increased groundwater, or base flow. Decreasing INFIL will produce the opposite result. Although INFIL and LZSN control the volume of runoff from groundwater, the KK24 parameter controls the rate of outflow from the groundwater storage.

In watersheds with no groundwater component, the K24L parameter is used to direct the groundwater contributions to deep inactive groundwater storage that does not contribute to runoff (K24L = 1.0 in this case). For these watersheds, runoff cannot be transferred from one season or month to another, and the INFIL parameter is used in conjunction with LZSN to obtain the annual and individual monthly water balance.

K24L is normally set equal to 0.0 in watersheds with a signficiant baseflow or groundwater component, and the KV parameter can then be used to adjust the seasonal distribution of baseflow volumes.

6.2.3 Initial Soil Moisture Conditions

Continuous simulation is a prerequisite for correct modeling of individual events. The initial conditions that influence the magnitude and character of events are the result of hydrologic processes occurring between events. Thus, the choice of initial conditions for the first year of simulation is an important consideration and can be misleading if not properly selected.

The initial values for UZS, LZS, and SGW should be chosen according to the guidelines in Section 5.3.1 and readjusted after the first calibration run. UZS, LZS, and SGW for the starting day of simulation should be reset approximately to the values for the corresponding day in subsequent years of simulation. Thus, if simulation begins in October, the soil moisture conditions in subsequent Octobers in the calibration period can usually be used as likely initial conditions for the simulation. Meteorologic conditions preceeding each October should also be examined to insure that the assumption of similar soil moisture conditions is realistic.

6.2.4 Storm Event Simulation

When annual and monthly runoff volumes are adequately simulated, hydrographs for selected storm events can be effectively altered with the UZSN and INTER parameters to better agree with observed values. Also, minor adjustments to the INFIL parameter can be used to improve simulated hydrographs; however, adjustments to INFIL should be minimal to prevent disruption of the established annual and monthly water balance. Characteristics of the overland flow plane (i.e. NN, L, SS) also have a major affect on hydrograph shape; the pertinent parameters should be checked to insure that their values are reasonable.

Parameter adjustment should be concluded when changes do not produce an overall improvement in the simulation. One event should not be matched at the expense of other events in the calibration period. Recommended guidelines for adjustment of hydrograph shape are:

(1) The interflow parameter, INTER, can be used effectively to alter hydrograph shape after storm runoff volumes have been correctly adjusted. INTER has a minimal effect on runoff volumes. As shown in Figure 6.1 where the values of INTER were (a) 1.4, (b) 1.8, and (c) 1.0, increasing INTER will reduce peak flows and prolong recession of the hydrograph. Decreasing INTER has the opposite effect. On large watersheds where storm events extend over a number of days, the IRC parameter can be used to adjust the recession of the interflow portion of the hydrograph to further improve the simulation.

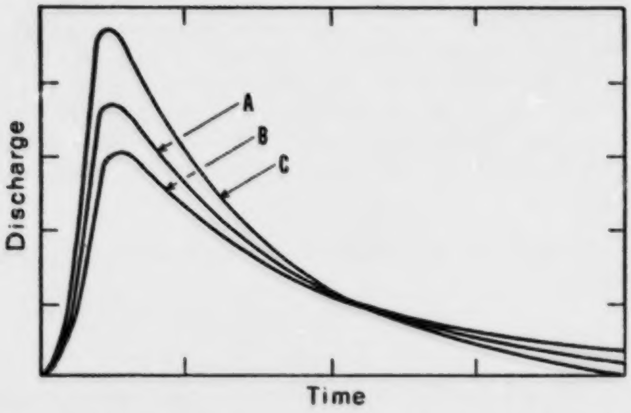


Figure 6.1 Example of response to the INTER parameter

(2) The UZSN parameter also affects hydrograph shape. Decreasing UZSN will generally increase flows especially during the initial portions, or rising limb, of the hydrograph. Low UZSN values are indicative of highly responsive watersheds where the surface runoff component is dominant. Increasing UZSN will have the opposite effect, and high UZSN values are common on watersheds with significant subsurface flow and interflow components. Caution should be exercised when adjusting hydrograph shape with the UZSN parameters to insure that the overall water balance is not significantly affected.

(3) The INFIL parameter can be used for minor adjustments to storm runoff volumes and distribution. As with UZSN, changes to INFIL can affect the water balance; thus, modifications should be minor.

When the calibration of storm hydrographs is completed, the entire hydrologic calibration is finished, and sediment calibration can be initiated.

6.3 SEDIMENT CALIBRATION

As indicated in the description of the calibration process, sediment calibration follows the hydrologic calibration and must preceed the adjustment of the pesticide or nutrient parameters.

Sediment parameter calibration is more uncertain than hydrologic calibration due to less experience with sediment simulation in different regions of the country. The process is analogous; the major sediment parameters are modified to increase agreement between simulated and recorded monthly sediment loss and storm event sediment removal. However, observed monthly sediment loss is often not available, and the sediment calibration parameters are not as distinctly separated between those that affect monthly sediment and those that control storm sediment loss.

In general, sediment calibration involves the development of an approximate equilibrium or balance between the generation of sediment particles on one hand and the washoff or transport of sediment on the other hand. Thus, the sediment storage on the land surface should not be continually increasing or decreasing throughout the calibration period. Alternating dry and wet periods of variable length and intensity, and man-made disturbance (for example, tillage) will cause substantial variations in the detached sediment storage. However, the overall trend should be relatively stable. This equilibrium must be developed and exist in conjuction with the accurate simulation of monthly and storm event sediment loss. The detached sediment storage is printed in monthly and annual summaries and whenever modified by tillage operations.

The following sections provide guidelines and recommendations to assist in sediment calibration.

6.3.1 Sediment Balance

On pervious areas, KRER and SCMPAC are the major parameters that control the availability of detached sediment on the land surface, while KSER and JSER control the sediment washoff. The daily compaction or removal of detached sediments by SCMPAC will dominate sediment availibility for land surfaces with high cover factors (COVPMO). On exposed land surfaces, sediment generation by soil splash is important and is controlled largely by the KRER parameter. To offset the sediment availability on pervious areas, the KSER and JSER parameters control sediment washoff to prevent continually increasing or decreasing sediment on the land surface. Thus, a balance must be established between the KRER and SCMPAC parameters and the KSER and JSER parameters to develop the equilibrium described above.

6.3.2 Primary Calibration Parameters

The exponents of soil splash (JRER) and sediment washoff (JSER) are reasonably well defined. Thus, the parameters that receive major consideration during sediment calibration are the coefficient of soil splash, KRER, and the coefficient of sediment washoff, KSER. These parameters should be considered first in establishing the sediment balance.

6.3.3 Sediment Fines Storage

In general, an increasing sediment storage throughout the calibration period indicates that either soil fines generation is too high, or sediment washoff is too low. Examination of individual events will confirm whether or not sediment washoff is undersimulated. A continually decreasing sediment storage can be analyzed in an analogous manner except the SCMPAC parameter can be suspected of being too high. Also, tillage operations will usually cause major changes in the detached sediment storage, so two or more years of simulation may be needed to establish the overall behavior of the sediment storage.

6.3.4 Transport Limiting vs. Sediment Limiting

The sediment washoff during each simulation interval is equal to the smaller of two values; the transport capacity of overland flow or the sediment available for transport from the land surface. To indicate which condition is occurring, an asterisk (*) is printed in the calibration output whenever sediment washoff is limited by the accumulated sediment in each areal block (Appendix B). Thus, when no asterisks are printed, washoff is occurring at the estimated transport capacity of overland flow in all blocks. Generally, washoff will be at capacity (no asterisks) during the beginning intervals of a significant storm event; this simulates the "first flush" effect observed in many nonpoint pollution studies. As the surface sediment storage is reduced, washoff may be limited by the sediment storage in the blocks producing the most surface runoff during the middle or latter part of storm events. However, for very small events, overland flow will be quite small and washoff can occur at capacity throughout. Also, on agricultural and construction areas, washoff will likely occur at capacity for an extended period of time due to the large amount of sediment available for transport.

6.3.5 Tillage Operations

The impact of tillage operations on sediment production is represented in the model by resetting the detached sediment storage to the value of SRERTL on the day of the operation as specified by TIMTIL and YRTIL. We expect that storms occurring soon after tillage will transport sediment at or near capacity (no asterisks printed), while storms occurring an extended time (2 to 3 months) after tillage will produce sediment limited by availability of detached material (asterisks printed). The SRERTL and SCMPAC parameters should be evaluated conjunctively so that conditions highly susceptible to erosion exist soon after tillage, but not later in the growing season. Also, the pattern of crop canopy development affects the erosion potential.

6.3.6 Soil Splash and Transport Exponents

Using the information provided by the asterisks (described above) minor adjustments in JRER and JSER, can be used to alter the shape of the sediment graph for storm events. When available sediment is limiting (asterisks printed), increasing JRER will tend to increase peak values and decrease low values in the sediment graph. Decreasing JRER will have the opposite effect tending to decrease the variability of simulated values. When sediment is not limiting (no asterisks printed), the JSER parameter will produce the same effect. Increasing JSER will increase variability while decreasing it will decrease variability. These parameters will also influence the overall sediment balance, but if parameter adjustments are minor the impact should not be significant.

6.3.7 Concentration vs. Mass Removal

Sediment calibration for selected storm events can be performed by comparing simulated and recorded concentrations or mass removal. For sediment and other nonpoint pollutants, including pesticides and nutrients, mass removal in terms of mass per unit time (gm/min) is often more indicative of the washoff mechanism than instantaneous observed concentrations. However, the available data will often govern the type of comparison performed.

6.4 PESTICIDE CALIBRATION

Ideally pesticide simulation should require little, if any, calibration since all the pesticide parameters represent characteristics that can be determined in laboratory experiments. However, inaccuracies in the pesticide algorithms, discrepancies between laboratory and field conditions, variability in measured laboratory values, or lack of pertinent laboratory values will usually require some adjustment or calibration of initial parameter values. Calibration should be done by comparing simulated values with measured field data. If no field data are available, data from watersheds under similar conditions and personal experience should be used to evaluate the simulated values.

Presently very little experience exists as a basis for adjusting the pesticide parameters. From applications of the ARM Model in Georgia and

Michigan, the recommended procedures for pesticide calibration are to adjust the parameters for the following processes in the order given:

(1) pesticide degradation
(2) pesticide leaching and vertical distribution
(3) pesticide adsorption/desorption characteristics
(4) pesticide runoff evaluation

Obviously, the above processes are interrelated and any calibration procedure will involve iterative examinations of the simulation results as the parameter values are further refined. The intent of pesticide calibration is to: (1) obtain the correct time distribution of the amount of pesticide in the soil following application by adjustment of the degradation parameters (KDG, DDG, YDG); (2) obtain the correct vertical distribution of pesticides in the various soil layers by adjusting the leaching factors (UZF, LZF); and (3) obtain the correct partitioning between solution and sediment-associated pesticide by adjusting the adorption/desorption parameters (DD, K, N, NP). With this procedure in mind, the following steps and guidelines for pesticide calibration are recommended.

6.4.1 Pesticide Degradation or Persistence

The degradation rates, KDG, and the corresponding time periods as specified by DDG and YDG should be adjusted to represent the persistence curve of the pesticide in the soil. This curve can be evaluated from the output of daily production runs (HYCAL=PROD and PRINT=DAYS) which indicates the amount of pesticide present in the soil at the end of each day.

Many pesticides will degrade to negligible levels in the soil within one to two months following application. Also, decay rates will often be much higher in the first days and weeks after application than later in the season. Atrazine and diphenamid have been shown to exhibit degradation rates that are substantially reduced after the first major rainfall event after application. If this occurs, a single-first order degradation rate will usually underestimate degradation immediately after application and overestimate degradation later in the growing season. Thus the KDG, DDG, and YDG parameters can be used to employ different rates to obtain a stepwise approximation to the actual degradation curve.

Degradation often accounts for the loss of over 90 percent of the applied pesticide. If no soil pesticide measurements are available, the degradation rates can be adjusted to bring the simulated runoff concentration in line with observed values. This assumes that the partitioning characteristics are reasonably accurate.

6.4.2 Vertical Distribution and Leaching

After the correct pesticide persistence has been approximated, the vertical distribution can be adjusted using the upper zone and lower zone chemical leaching factors, UZF and LZF. Soluble chemicals applied to the surface zone will be washed to the upper and lower zones with the first rainfall event after application. Considering the small depth of the surface zone, this is not an unreasonable assumption, and can only be corrected with additional research and model development (Donigian, et al. 1977).

Increasing UZF and LZF beyond their default values of 1.0 will decrease the chemical leaching from their respective zones. On the other hand, decreasing these factors to values less than 1.0 will increase chemical leaching. Guidelines for evaluating UZF and LZF are included in Section 5.3.4.

6.4.3 Pesticide Adsorption/Desorption

(1) The DD parameter is used for pesticides that are irreversibly bound to soil particles and will not detach under repeated washings. High values of DD will retain all the applied pesticide in the surface zone, and pesticide loss in runoff will occur only by attachment to the eroded sediment. In these cases, the pesticide concentration on the eroded sediment will remain reasonably constant during an event and will decrease with time following application due to degradation. In effect, the eroded pesticide concentration is approximately equal to the soil pesticide concentration and its initial value is equal to the pesticide application divided by the mass of soil in the surface zone. For these irreversibly bound pesticides, concentrations on eroded sediment can be uniformly adjusted over the entire growing season by adjusting the parameters that affect the surface zone soil mass (BDSZ or SZDPTH), and the decrease in concentration during the growing season is affected by the degradation rates. Guidelines for evaluating DD are provided in Section 5.3.5.

(2) For zero values of DD or pesticide application amounts that exceed the permanently fixed capacity of the soil (as specified by DD), the adsorption/desorption parameters (K, N, NP) determine the partitioning between the solution and adsorbed phases. As shown in Figure 2.4, pesticide amounts in excess of the permanent fixed capacity enter the adsorption/desorption algorithms to evaluate the equilibrium solution and adsorbed concentrations. These equilibrium calculations are performed in each time interval and for each soil layer. The calculated pesticide solution concentration determines the pesticide mass lost by water movement, while the adsorbed concentration calculates the pesticide mass that is lost by erosion from the surface layer or the amount that remains adsorbed in the other soil layers.

Figure 6.2 shows the relationship between the K, N, and NP parameters on a logarithmic graph. All three parameters are used when the non-single-valued (NSV) algorithm is employed; only K and N are used for the single-valued (SV) algorithm. Figure 6.2 shows that:

(a) The input K value is the adsorbed concentration (in ppm or g/gm) at a solution concentration of 1.0 mg/l. Thus, increasing K will increase the simulated adsorbed concentration, and vice versa, for either the SV or NSV algorithms.

(b) For the SV algorithm, the value 1/N determines the slope of the line which rotates about point A. Thus, increasing N will decrease the slope resulting in higher adsorbed concentrations when c < 1.0 and lower adsorbed concentrations when c > 1.0. Decreasing N will produce the opposite effect. Except for high application amounts or immediately after application, pesticide solution concentrations are generally less than 1.0 and thus increasing N usually increases the adsorbed concentration.

(c) For NSV simulation, the NP parameter affects the slope of the branching desorption curves. Thus, increasing NP will increase adsorbed concentrations and vice versa. The affects of NP and N are not analogous, since each desorption curve is defined by NP, the maximum solution concentration attained before desorption, and a new K value calculated by the model (Donigian and Crawford 1976a).

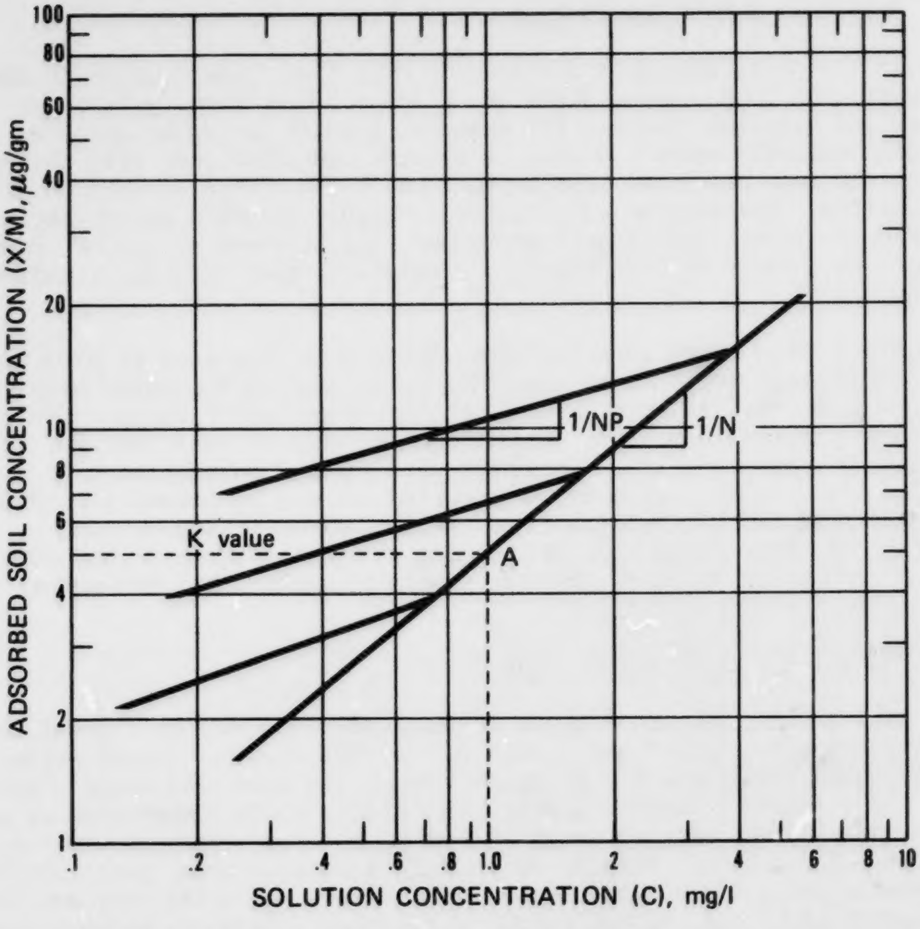


Figure 6.2 Relationships of pesticide adsorption/desorption parameters

Additional research and testing is needed to determine whether the SV or NSV algorithms or a dynamic approach best represents the field behavior of pesticides. In general, the NSV algorithm simulates higher adsorbed sediment concentrations and appears to better represent the ratio of solution to adsorbed pesticide in runoff during the growing season. However, the NSV algorithm requires more computer time and it is not clear that different K and N values with the SV algorithm could not produce equally representative results.

The user will note that changes in the adsorption/desorption parameters will also cause changes in the vertical distribution, since a shift in partitioning to higher adsorbed concentrations will decrease the solution pesticide that can move vertically with infiltrating and percolating water. Thus UZF and LZF may need to be readjusted as a result of changes in the adsorption/desorption parameters.

6.4.4 Pesticide Runoff Calibration

Shifts in the partitioning of a pesticide will also cause changes in the total pesticide loss because different transport components affect the adsorbed and solution phases. For example, a shift to higher adsorbed concentrations will generally lead to greater pesticide loss with the eroded sediment and less pesticide loss by the runoff components of overland flow and interflow. The reverse is also true: higher solution concentrations will produce greater pesticide loss by overland flow and interflow. However, the absolute changes will depend on the relative total amounts of sediment loss and runoff.

For highly soluble pesticides (and nutrient forms), the loss of solution pesticide has been found to be sensitive to changes in the hydrologic interflow parameter, INTER. INTER controls the volume of the interflow components of runoff and hence the division of surface water between interflow and overland flow. Chemicals with minimal adsorption to soil particles are simulated as being transported largely by interflow. Thus, some adjustment of the INTER parameter may be needed to improve the simulation of these chemicals. Increasing INTER will increase the interflow component and the associated loss of soluble chemicals, and decreasing INTER has the opposite effect.

6.4.5 Monthly and Storm Comparisons

To the extent possible, comparisons of pesticide loss in runoff should be done for both storm graphs and cumulative monthly values. Annual values generally have little meaning since most pesticide loss will occur within two to three months following application. Also, storm comparisons of mass removal (gm/min) may be more meaningful than pesticide concentrations since the latter can be highly erratic with little impact on total pesticide loss. Mass removal shows the direct relationship between pesticide loss and its transporting component, either runoff or sediment. However, concentrations are important for examining ecologic and toxic impacts on receiving waters. The type of information used in comparing simulated and recorded values will depend on the available data and the problems analyzed.

Whatever comparisons are made, pesticide calibration should be performed on periods when the transport components, runoff and sediment, are reasonably well simulated. Some consistency should exist between the pesticide simulation and the transport components. Thus, if sediment is the major transport component and it is oversimulated, then the pesticides values should be oversimulated also. This consistency will indicate that the correct mechanisms are being simulated even if the simulated and recorded values are not in complete agreement.

6.5 NUTRIENT CALIBRATION

Nutrient calibration begins with analysis and comparison of the production run soil storages (HYCAL=PROD, INTR=DAYS) with the observed soil nutrient data. Soil nutrient data obtained from sampling throughout the watershed for the period of calibration provides valuable information for the calibration of the nutrient parameters of the ARM Model. If no soil nutrient data are available, calibration consists of merely estimating reasonable nutrient storages and comparing the recorded and simulated nutrient runoff results. However, all the simulation results (storages and runoff) should be evaluated for reasonableness based on personal experience and data from similar watersheds.

With or without observed data, the order of calibration is the same and is analogous to the pesticide calibration procedures. (Review of Section 6.4 may assist the understanding of this section.)

Nutrient calibration involves the establishment of reasonable soil nutrient storages through adjustment of percolation parameters, plant uptake parameters, and reaction rates, followed by evaluation of nutrient runoff and refinement of pertinent parameters. The recommended order and steps in the procedure are:

(1) adjustment of percolation factors
(2) calibration of plant uptake parameters
(3) calibration of remaining soil nutrient reaction rates
(4) evaluation of nutrient runoff and refinement of related parameters

The first three steps should be done by comparing simulated and recorded soil storages. As with pesticide calibration, some iteration of the steps is often required. Parameter values may need to be readjusted as later steps affect prior adjustments, but the order designated should help to minimize the number of iterations in the calibration procedure.

6.5.1 Nutrient Percolation

The percolation factors, UZF and LZF, should be calibrated on downward movement of chloride. Chloride merely acts as a tracer. Increasing UZF will decrease the leaching of chloride from the upper zone (see Sections 5.3.4 and 6.4 for discussions of these parameters). If necessary, increasing the hydrology parameter UZSN will also decrease the leaching since this will increase moisture retention in the upper zone. However, changing UZSN can have a noticeable impact on the hydrologic simulation.

Experience to date on small watersheds indicates that LZF may not have to be adjusted from its default value of 1.0; larger watersheds with nutrient contributions to groundwater may need larger values. These percolation factors once calibrated should not have to be readjusted unless further changes in the hydrology parameters are made.

6.5.2 Plant Uptake of Nutrients

The plant uptake factors, ULUPTK and LZUPTK, and both the nitrogen and phosphorus reaction rates, KPL, should be adjusted following the percolation factors. ULUPTK (for surface and upper zones) and LZUPTK (for lower zone) can be used to distribute the estimated total uptake both over time and between the zones. Adjustment of KPL, the maximum uptake rate, can be used to obtain the desired amounts of nitrogen and phosphorus uptake. The amounts and distribution can be estimated from the guidelines given in Section 5.3.6. All the uptake parameters should be evaluated initially from the guidelines provided. However, since plant uptake is dependent upon the availability of solution nitrate and phosphate, these initial values will usually need adjustment following calibration of the other reaction rates.

6.5.3 Soil Nutrient Reaction Rates

Once the plant requirements are satisfied, the other soil reaction rates can be calibrated. These rates must also be adjusted separately for each soil zone. The surface and upper zone rates and storages have a direct effect on the nutrients transported by sediment, overland flow, and interflow. The lower zone rates and storages affect nutrient percolation to groundwater. The three major rates to be adjusted in these zones (and in groundwater when groundwater reactions are simulated) are KD, K1, and KSA/KAS. The denitrification rate, KD, may have to be increased if too much nitrogen remains in storage after the major removals by leaching and plant uptake have been determined. The nitrification rate, K1, can be adjusted to get the proper balance between NO_3-N and NH_4-N. The proper balance depends on a variety of factors including the timing and form of fertilizer application, the growing crop, the season of the year, and soil characteristics. Consultation with soil scientists and agricultural extension personnel may be needed to assist the evaluation of this and other aspects of the soil nutrient simulation.

The desorption, KAS, and the adsorption rate, KSA, will also affect nitrification by its impact on the amount of solution NH_4-N available for nitrification (oxidation) by the K1 rate. In addition, the respective nitrogen and phosphorus KAS and KSA reaction rates will influence the leaching, uptake, and runoff of ammonium and soluble phosphate by determining the amounts of each in solution form.

The user will note that all the soil nutrient reactions are inhibited when zero moisture levels occur (that is, zero values for the soil moisture storages). This occurs frequently in the surface zone which contains moisture only during or immediately following storm events. The upper zone can also experience zero moisture when small UZSN values are used.

6.5.4 Nutrient Runoff

Once the reaction rates have been calibrated with soil data, the focus can be on the nutrient runoff results. Simulated monthly and daily nutrient runoff amounts should be compared with observed data. From calibration run output (HYCAL=CALB and PRINT=INTR), simulated nutrient mass removal and concentrations should be compared with recorded data for individual storm events. As with the pesticide simulation, some degree of consistency should exist between nutrient runoff simulation and the runoff and sediment simulation, since the nutrient simulation can only be as good as the simulation of its transport components.

Some other adjustments may be necessary when comparing the runoff results. The model's main pathway of soluble nutrient removal (mainly Cl, NO_3, and PO_4) is by the interflow component of runoff. Therefore, adjustment of the hydrology interflow parameter, INTER, has been very useful in calibration of soluble nutrients in the runoff (Section 6.4).

Sediment associated nutrients are removed only from the surface layer in the model. Consequently, the form and amount of adsorbed nutrient forms in the surface zone controls the amount available for removal on eroded sediment. Application of the fertilizer directly to the adsorbed phase in the surface zone will cause more nutrients to be in the eroded sediments. In addition, application of fertilizer in both the surface and upper zone in the adsorbed phase will result in less fertilizer being leached from these zones after application. The adsorbed nutrient forms will remain in the surface and upper zones, and will thus be available for transport for a longer period of time than if they were applied in the soluble form. In these cases, the desorption rates for nitrogen, phosphorus, and the K1 rate controls the conversion to the more mobile solution forms, which are readily transported with the moving water.

In general, analysis of the nutrient runoff results will indicate needed changes in the nutrient storages that are usually effected by refinements in the reaction rates. Alternating analyses of nutrient storages, reaction rates, and runoff results is usually iterated until a satisfactory calibration is obtained (Section 6.6). The user should attempt to keep parameter adjustment within the expected ranges discussed in the parameter evaluation guidelines (Section 5.3.6) unless evidence exists to the contrary.

6.6 HOW MUCH CALIBRATION?

A common question that is asked by model users concerns the extent of calibration or parameter adjustment necessary before one can say that the model is "calibrated" to the test watershed. Obviously this depends to some extent on how well the initial parameter values are estimated. But beyond that, the question is really "How close should the simulated and recorded values be before calibration can be terminated?" The answer to this question depends on a number of factors including the extent and reliability of the available data, the problems analyzed vs. the model capabilities, and the allowable time and costs for calibration.

6.6.1 Data Problems

The available data are often the most severe limitation on calibration especially for water quality variables. A common mistake by model users is to accept the observed data as being absolutely accurate. In fact, any measurement obtained under field or natural conditions will usually contain at least a 5 to 10 percent variation from the actual or true value. Moreover, instantaneous or short time interval measurements commonly show variations of 10 to 20 percent and greater for flow or concentration values. Usually annual volumes and total loss measurements are the most accurate except when a persistent bias exists in the measurement technique.

The assumption of uniform areal precipitation is a major source of error with direct effects on the simulation since precipitation is the driving force of the ARM Model. Precipitation is rarely uniform and is highly nonuniform in thunderstorm prone regions of the country. This nonuniformity makes simulation of thunderstorms difficult since the actual rainfall is unknown if the recording gage does not adequately represent the rainfall pattern.

The user should be aware of the measurement techniques and the resulting confidence limits of the observed values for both the input meteorologic data and the runoff or soil calibration data. Simulated values within the confidence limits of the observed calibration data cannot be improved upon; this signals a reasonable end to calibration. However, this is not an absolute criterion since a good overall calibration can include simulated individual storm events or instantaneous values with larger variations than the accepted confidence limits. In such cases, analysis of the discrepancies and personal judgement must be called upon to decide if calibration is sufficient.

6.6.2 Problems Analyzed vs. Model Capabilities

Another source of frustration in model calibration is the attempt to calibrate a model for conditions or processes that the model cannot adequately represent. Prime examples in the ARM Model are the hydrologic impact of tillage operations and simulation of watersheds where channel processes are significant. The ARM Model cannot presently represent the effects of specific tillage operations on runoff and soil moisture; additional research is needed to determine how these effects can be simulated. Storms occurring soon after a tillage operation may not be well simulated for runoff, but this effect decreases with time since the tillage. Calibration of parameters to better simulate these events will bias the rest of the simulation and produce a biased set of hydrologic parameters.

Similarly, calibration of the ARM Model on watersheds where channel processes are important will usually lead to biased hydrologic parameters. The hydrograph delay that is reflected in the recorded data can lead to calibration of unusually large interflow and overland flow length parameters. Sediment parameters would also be biased. In effect, these parameter adjustments are attempts to account for processes that the model does not simulate.

To avoid these problems, the user should have a basic understanding of the processes that are occurring on the watershed, the processes simulated by the ARM Model, and their method of representation in the model. Study of the ARM Model algorithms provides an additional benefit since the user will acquire a better understanding of the role of model parameters and the impact of parameter adjustments. Calibration can be expedited with this knowledge, and with the realization that certain processes affecting the observed data are not represented in the model. Parameter adjustments to circumvent such model limitations are both inappropriate and futile.

6.6.3 Guidelines

In many applications of the ARM Model, the time and costs budgeted to calibration will determine the level of effort expended. Calibration is a critical step in any model application and may require 30 to 50 percent of the total project resources. Its importance cannot be understated. The arguments provided above should not be used to justify reducing the time and costs required for a reasonable calibration. However, our experience has shown that many diligent users will often spend too much time on calibration due to insufficient observed data, ignorance of the accuracy of the data, and misconceptions of model capabilities and parameter sensitivities.

The agreement between simulated and recorded values required for an adequate calibration is highly dependent on the specific watershed, data conditions, and problems analyzed. Very little quantitative information exists to provide guidelines for evaluating a calibration. However, from our experience in applying the ARM Model and related models and within the framework of the considerations discussed above, the following general guidelines for characterizing a calibration are provided to assist potential model users:

Difference Between Simulated and Recorded Values (percent)

	Calibration Results		
	Very Good	Good	Fair
Hydrology	<10	10-15	15-25
Sediment	<15	15-25	25-35
Pesticides/Nutrients	<20	20-30	30-40

The above percent variations largely apply to annual and monthly values for runoff, sediment, and pesticide/nutrient loss. Individual events may show considerably larger variation for many reasons with little impact on the overall calibration. These values should be used only as approximate guidelines. The user should attempt to obtain the best calibration possible within the limitations of the available data, the model capabilities, and the allowable budget.

6.7 CONCLUSION

The use of a continuous simulation model provides insight into the relationships among the various components of the hydrologic cycle and water quality processes. A model cannot be applied without understanding these relationships, yet the process of modeling itself is instructive in developing this understanding. The calibration process described above requires such an understanding of the physical process being simulated, the method of representation, and the impact of critical ARM Model parameters. It is not a simple procedure. However, study of the parameter definitions, the algorithm formulation, and the above guidelines should allow the user to become reasonably effective in calibrating and applying the ARM Model.

SECTION 7

SIMULATION ANALYSIS AND APPLICATIONS

7.1 METHODS OF ANALYSIS

Since the ARM Model produces continuous runoff quantity and quality information for any period of input meteorologic data, how this information is analyzed is a critical consideration in any application of the model. The possible methods of analysis include evaluation of (1) single or so-called "design" storm events, (2) mean monthly, seasonal, or annual values, and (3) frequency or probability distributions of runoff and pollutant concentrations or loadings. Obviously each method of analysis has different requirements of observed data, labor effort, technical expertise, and computer cost. The analyst must consider these factors in choosing a particular analysis procedure for the problem being analyzed. However, each method of analysis does not produce the same information and can lead to different decisions if choices are to be made for use, management, or regulatory practices of agricultural lands.

The ARM Model can be used to produce the information necessary for each of the above analysis methods or others. However, we strongly advise against the use of the ARM Model in single or design storm event analysis for the following reasons:

(1) The model should not be calibrated on single storms in separate model runs because the initial moisture, sediment, and soil conditions are usually unknown and will often bias the simulation and the calibrated parameters. Model parameters must be calibrated with continuous runs for extended periods of time.

(2) The choice of a single storm is usually an arbitrary decision. Often the largest storm is chosen and no frequency can be assigned to specify how often the storm will occur. Rainfall frequency cannot be assigned to runoff, and neither rainfall nor runoff frequency can be assigned to the runoff quality.

(3) Simulation results for a single storm event can be highly variable for the reasons discussed in Section 6. Also, critical events for pollutant loadings cannot be necessarily predicted. Alternative plans should be evaluated under a variety of environmental and meteorologic conditions.

Monthly, seasonal, or annual values and frequency distributions can be obtained from information produced by the same ARM Model run. The model provides the monthly and annual values by summing the simulation results in each time interval. These summary values of runoff, sediment loss, or pesticide/nutrient loadings obtained from separate model runs for alternative land use or management conditions can provide the basis for deciding among the various alternatives. Simulation runs for at least 3 to 5 yr, and preferably up to 10 yr, should be performed to obtain the mean monthly, seasonal, or annual values. The longer runs can also provide an indication of the variability expected about the mean value. Runoff volumes and pollutant loadings are the type of information that is usually reported in this type of analysis because mean concentration values for long time spans are not especially useful in characterizing the highly intermittent problems of nonpoint pollution.

To fully exploit the information provided by continuous simulation, frequency analysis of the simulated time series information is recommended in order to characterize the frequency or probability of occurrence of runoff and pollutant levels under a wide range of meteorologic and environmental conditions. The use of derived frequency distributions obtained from continuous simulation for evaluating water quality plans is described by Donigian and Linsley (1976).

Figures 7.1 and 7.2 are examples of frequency distributions obtained from the analysis of ARM Model simulation runs for alternative soil and water conservation practices.* This information was developed as part of an ongoing research project by Cornell University and sponsored by EPA to evaluate the effectiveness of soil and water conservation practices for pollution control (Cornell University 1976). Figure 7.1 shows the runoff, sediment concentration, and sediment flux (mass removal) curves, while Figure 7.2 includes the curves for total pesticide flux and concentrations in the runoff water and eroded sediment. Simulation runs of 3.4 years on the P2 watershed (1.3 ha) in Watkinsville, Georgia provided the continuous time series information to develop these curves. The various practices were represented by assuming changes in the relevant hydrologic and sediment parameters.

The curves are presented in terms of the percent of time the particular variable (for example, runoff in cms) is greater than the ordinate value. Thus, Figure 7.1 shows that sediment concentrations under terracing and/or contouring are greater than 8.0 gm/l for 2 percent of the time (time during which runoff is occurring), whereas no conservation practices would produce sediment concentration greater than 11.0 gm/l for 2 percent of the time. Similarly, Figure 7.2 shows that the pesticide concentration in water for 1.0 percent of the time will be greater than 1.2 mg/l for base/non-conservation conditions and greater than 0.4 mg/l for contouring and terracing. In this way frequency curves can be analyzed to determine how often specific runoff volumes, flow rates, pollutant concentrations, or flux rates will occur. For ecologic impact, the frequency curves and

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*Neither Version I nor Version II of the ARM Model includes the capability to generate these curves. Slight modification of the code and a program to perform the frequency analysis can be obtained from the Environmental Research Laboratory, Athens, GA. Contact: Lee Mulkey, (404) 546-3581.

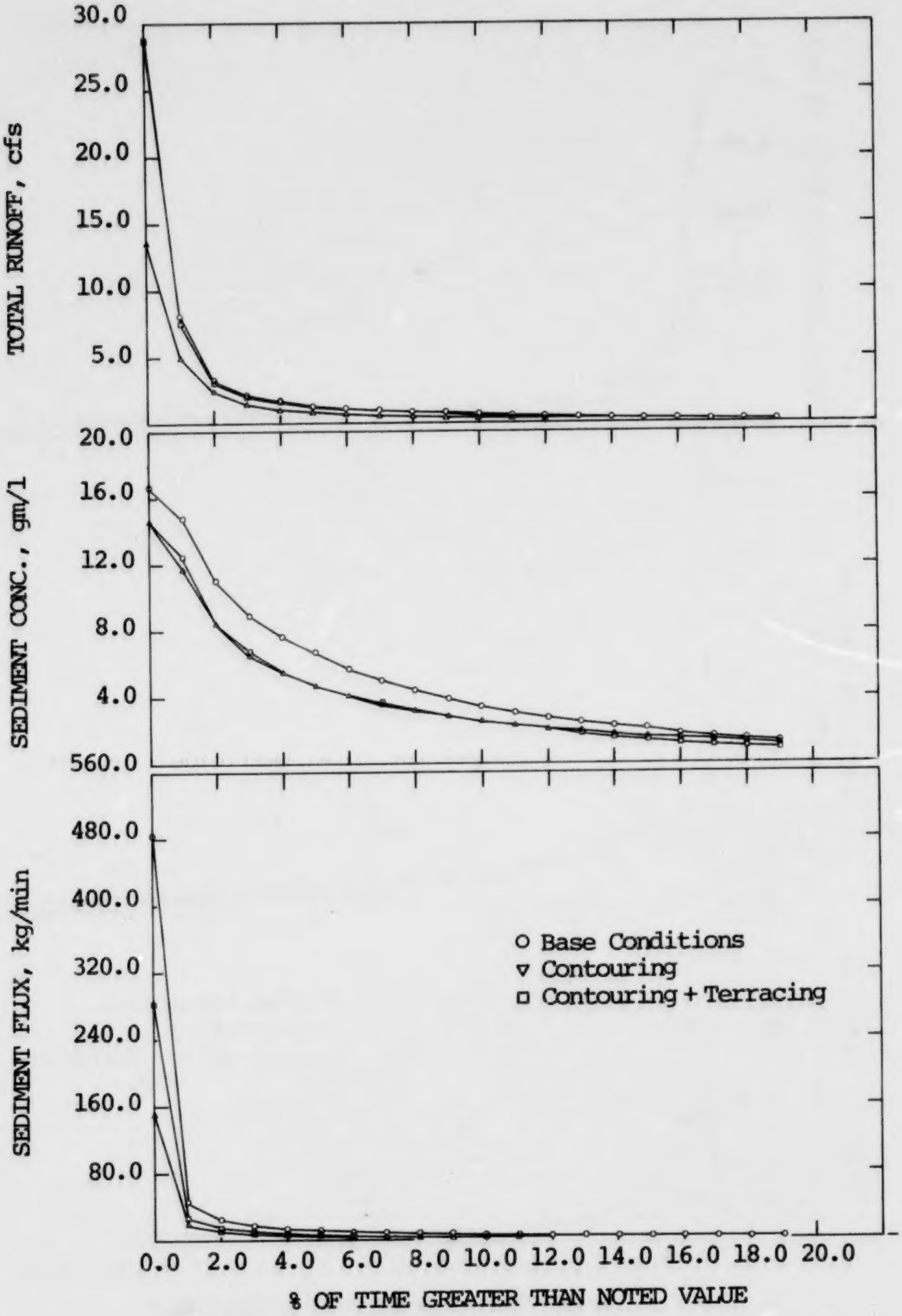

Figure 7.1 Runoff and sediment frequency analysis

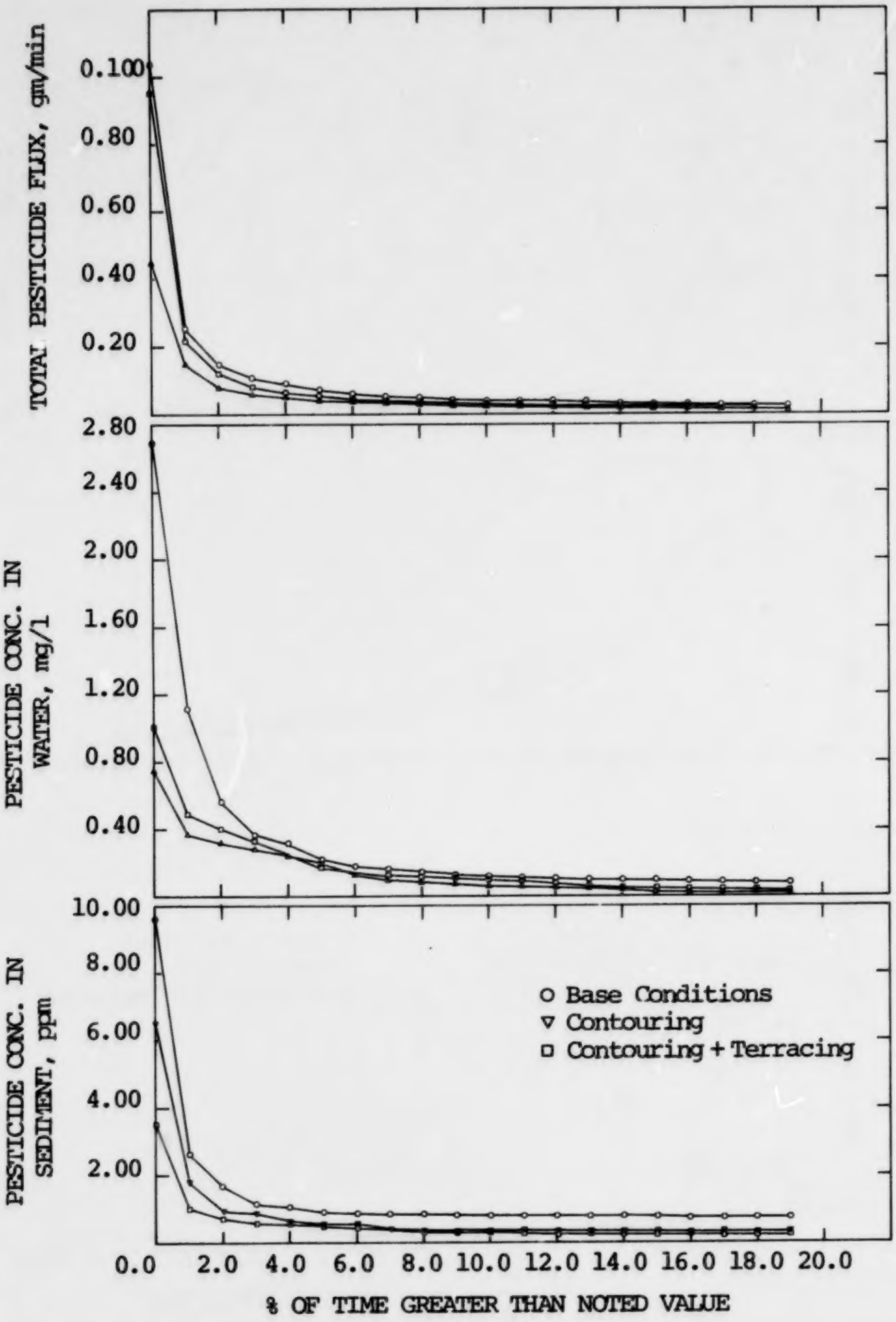

Figure 7.2 Pesticide frequency analysis

toxicity data can be used to estimate how often acute or chronic pesticide levels toxic to specific organisms will exist.

To evaluate the net or overall impact of the alternative practices, the area beneath the curve for each practice can be calculated and compared from elementary decision theory this area represents the expected value of the ordinate variable under all conditions; that is, the value of the variable times its probability of occurrence, summed over all possible occurrences. For example, the area beneath the base sediment curve in Figure 7.1 is the expected sediment concentration without conservation practices. It is measured in units of the y-axis, mg/l; each block (1 x-axis unit x 1 y-axis unit) is 0.08 mg/l (4 mg/l x .02). The differences in area beneath each curve, or the area between the curves, can be used to evaluate the impact of a particular practice. Table 7.1 lists the area beneath each frequency curve and the percent change for each practice from the base/non-conservation conditions. Evaluation of the overall effect of different practices is accomplished with this information for the runoff components of interest.

In summary, frequency analysis of the output obtained from the ARM Model simulation runs is recommended to effectively utilize continuous simulation. Total and mean values for runoff and pollutant loadings can complement the frequency analysis since both types of information are provided by the ARM Model.

7.2 APPLICATIONS

The ARM Model is specifically designed as a tool to evaluate the quantity and quality of agricultural runoff and the impacts of alternative management practices. Although testing has been limited to small agricultural watersheds, the model can be used in non-agricultural (and non-urban) areas since the processes and mechanisms simulated are universal. Urban areas cannot be simulated because the impervious land surface processes are not adequately represented.

Possible applications for the ARM Model include:

(1) Quantifying the runoff, sediment, pesticide, and nutrient content of agricultural runoff.

(2) Evaluating the runoff quality resulting from alternative levels of pesticide and fertilizer applications.

(3) Providing runoff components (quantity and quality) from non-urban areas as input to stream water quality models for comprehensive basin modeling.

(4) Evaluating ecologic effects resulting from the runoff of toxic substances.

(5) Evaluating the runoff quantity and quality resulting from alternative agricultural land management practices.

TABLE 7.1 FREQUENCY ANALYSIS OF ALTERNATIVE SOIL AND WATER CONSERVATION PRACTICES USING THE ARM MODEL[a]

	Expected Value[b]			Percent Change from Base Conditions	
	Base Conditions[c]	Contouring[d]	Contouring[d] and Terracing	Contouring	Contouring and Terracing
Total Runoff, cms x 10^{-2}	1.183	1.124	0.717	-5.0	-39.4
Overland Flow, cms x 10^{-2}	1.130	1.076	0.629	-4.8	-44.3
Interflow, cms x 10^{-2}	0.110	0.108	0.119	-1.8	+8.2
Sediment Loss					
Concentration, mg/l	1.161	0.875	0.938	-24.6	-19.2
Flux, kg/min	4.76	3.02	1.92	-36.6	-59.7
Total Pesticide Flux[e], gm/min	0.0215	0.0181	0.0115	-15.8	-46.5
Pesticide Loss in Water[e]					
Concentration, mg/l	0.0710	0.0428	0.0301	-39.7	-57.6
Flux, gm/min	0.0206	0.0176	0.0109	-14.6	-47.1
Pesticide Loss on Sediment[e]					
Concentration, ppm	0.3813	0.1680	0.1961	-55.9	-48.6
Flux, gm/min	0.0011	0.0009	0.0006	-18.2	-45.4

[a] These values were obtained from simulation runs with the ARM Model for 3.4 years on the P2 watershed (1.3 hectares) in Watkinsville, Georgia.

[b] Area beneath the corresponding frequency curve obtained from the simulated data. Not all of the frequency curves are shown in Figures 7.1 and 7.2.

[c] Base conditions refer to cropping parallel to the land slope.

[d] Contouring and terracing were represented by assuming changes in pertinent hydrologic and sediment parameters.

[e] Atrazine was the pesticide simulated.

Other applications and variations of those mentioned above are possible within the capabilities of the model and the ingenuity of the user.

Version II of the ARM Model is not a final product since further testing and evaluation is continuing to uncover model deficiencies and improve simulation of specific processes and agricultural practices. Further research is needed to better represent erosion processes, the effects of tillage operations, the transport of soluble substances, pesticide adsorption and degradation mechanisms, and nutrient transformations. However, in its present form the ARM Model can be an extremely useful tool for analysis of agricultural nonpoint pollution when it is applied with an awareness of its capabilities and limitations.

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APPENDIX A

SAMPLE INPUT SEQUENCES FOR THE ARM MODEL

TABLES

A1 Input Sequence for Hydrology (with snow) and Sediment Simulation with Meteorologic Data

A2 Input Sequence for Hydrology (without snow), Sediment, and Pesticide Simulation with Meteorologic Data

A3 Parameter Input Sequence for Hydrology (with snow), Sediment, and Nutrient Simulation

A4 Parameter Input Sequence for Hydrology (without snow) and Sediment Simulation with Runoff and Sediment Written to Disk

TABLE A1. INPUT SEQUENCE FOR HYDROLOGY (WITH SNOW) AND SEDIMENT SIMULATION WITH METEOROLOGIC DATA

```
//HARL7508 JOB 'A19$X2,444,.25,40','SNOW SAMPLE'
/*JOBPARM HOLD=JOB
//JOBLIB DD DSNAME=WYL.X2.A19.HD7508.ARMLM.DP100677,
// UNIT=DISK,VOL=SER=PUB005,DISP=(OLD,KEEP)
//STEP1 EXEC PGM=ARM
//SYSPRINT DD SYSOUT=A
//FT06F001 DD SYSOUT=A
//FT05F001 DD *
MICHIGAN P6 SNOW SAMPLE
HYDROLOGY AND SEDIMENT
HYCAL=CALB
INPUT=ENGL
OUTPUT=ENGL
PRINT=INTR
SNOW=YES
PEST=NO
NUTR=NO
ICHECK=ON
DISK=NO
 &CNTL  INTRVL= 5, HYMIN=  0.010, AREA=    1.98   &END
 &STRT BGNDAY= 1, BGNMON= 1, BGNYR= 1974   &END
 &ENDD ENDDAY=31, ENDMON= 1, ENDYR= 1974       &END
 &LND1 UZSN= 0.200, UZS=  0.500, LZSN=  9.00, LZS= 11.0   &END
 &LND2 L= 60.,SS= 0.060,NN= 0.2000,A= 0.0000,EPXM=0.1200,PETMUL=1.000  &END
 &LND3 K3=0.20,0.20,0.20,0.20,0.30,0.30,0.50,0.45,0.40,0.30,0.20,0.20 &END
 &LND4 INFIL=0.03,INTER=0.80,IRC=0.00,K24L= 1.00,KK24= 0.00,K24EL=0.00 &END
 &LND5 SGW=0.00,GWS=0.00,KV=0.00,ICS=0.00,OFS=0.00,IFS=0.000   &END
SNOWPRINT=YES
 &SN01 RADCON=1.0,CCFAC=1.00,SCF=1.40,ELDIF=0.0,IDNS= 0.14,F= 0.0 &END
 &SN02 DGM=0.0,WC=0.03,MPACK=1.0,EVAPSN=0.40,MELEV= 892.,TSNOW=32.00 &END
 &SN03 PACK= 0.0,DEPTH=  0.0 &END
 &SN04 PETMIN= 35.0,PETMAX= 40.0,WMUL= 1.0,RMUL= 1.00,KUGI= 0.0 &END
 &CROP COVPMO=0.0,0.0,0.0,0.0,0.0,0.05,0.55,0.90,0.90,0.80,0.0,0.0 &END
 &MUD1 TIMTIL= 140,136,0,0,0,0,0,0,0,0,0,0      &END
 &MUD2 YRTIL=   74,75,0,0,0,0,0,0,0,0,0,0    &END
 &MUD3 SRERTL= 1.00,0.80,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0      &END
 &SMDL JRER=2.2,KRER=0.15,JSER=1.40,KSER=0.5,SRERI=1.000,SCMPAC=0.001   &END
 EVAP74      15    26    42    82   107   140   258   189    90    48    29    17
 EVAP74      15    26    42    82   146   155   192    77    48    21    29    17
 EVAP74      15    26    42    82   100   140   236   119    48    27    29    17
 EVAP74      15    26    42    82   153   190   258    98    84    69    29    17
 EVAP74      15    26    42    82    54   176   162   126    84   101    29    17
 EVAP74      15    26    42    82   192   113   185   175    96    69    29    17
 EVAP74      15    26    42    82   107   162   155   154    84    48    29    17
 EVAP74      15    26    42    82    46    56   221    77   121    43    29    17
 EVAP74      15    26    42    82    23   148   288   147    96    69    29    17
 EVAP74      15    26    42    82    77   148   140   152    78    59    29    17
 EVAP74      15    26    42    82   130   106   185    84   103    80    29    17
```

(continue)

TABLE A1 (continued)

```
EVAP74     15    26    42    82   115    92   185   147    36    27    29    17
EVAP74     15    26    42    82    69   197   221   231    96    37    29    17
EVAP74     15    26    42    82    61   148   251   147    72    11    29    17
EVAP74     15    26    42    82   161   141   325   161   115    43    29    17
EVAP74     15    26    42    82    69   141   199   119    90    48    29    17
EVAP74     15    26    42    82    38    21   170    70   109    85    29    17
EVAP74     15    26    42    82   123    28   221   161    90    64    29    17
EVAP74     15    26    42    82   169    56   244   182    96    27    29    17
EVAP74     15    26    42    82   222   134   244   175   115    32    29    17
EVAP74     15    26    42    82   153   204   207   182    72    37    29    17
EVAP74     15    26    42    82   138   155    74   189   109   101    29    17
EVAP74     15    26    42    82   260   141    30   168    90    75    29    17
EVAP74     15    26    42    82   230    92   118   168   115    64    29    17
EVAP74     15    26    42    82   153   155   140   140   139    59    29    17
EVAP74     15    26    42    82   161   204   111   161   163    69    29    17
EVAP74     15    26    42    82   107   190   310   224   139    91    29    17
EVAP74     15    26    42    82     8   141   280    77    48    80    29    17
EVAP74     15          42    82    15   212   288   105    90    69    29    17
EVAP74     15          42    82   169   282   244   126    54    11    29    17
EVAP74     15          42         146         199   238          69          17
TEMP74  19 11 28 15 50 30 46 32 63 38 73 46 85 56 76 52 69 49 48 37 72 61 32 27
TEMP74  15  2 19 14 48 35 64 36 66 39 73 50 87 65 79 59 66 47 43 25 69 43 39 23
TEMP74  23 10 20 10 70 44 65 44 65 39 75 47 90 73 78 64 64 42 52 27 64 49 38 21
TEMP74  23 12 20  9 70 39 61 44 59 34 83 58 91 67 77 52 66 40 66 37 49 37 29 13
TEMP74  24  4 15- 4 52 33 45 39 58 36 83 60 74 53 76 56 68 41 71 51 40 32 32 16
TEMP74  24 10 19 10 59 38 49 25 50 29 82 64 81 56 82 55 71 43 71 57 42 36 36 11
TEMP74  22 12 19  3 56 44 50 33 52 26 81 65 89 56 81 52 71 46 65 36 52 29 36 27
TEMP74  14 -7 24-12 55 32 37 32 53 38 80 66 92 65 81 62 79 55 58 31 58 32 35 26
TEMP74  23  9 26  6 49 32 41 21 47 36 84 70 92 68 80 60 81 57 58 44 58 30 27 16
TEMP74  21 11 30  4 46 38 57 26 62 35 84 66 89 69 81 58 80 60 69 35 52 41 35 17
TEMP74  22 12 26  7 42 27 58 44 65 38 65 46 79 52 82 67 84 65 71 43 70 43 36 21
TEMP74  20  3 45 19 42 31 67 47 62 43 69 46 82 47 83 60 84 65 70 54 46 37 36 32
TEMP74  18  5 43 28 32 20 69 50 50 35 72 51 91 59 82 63 80 59 54 33 40 30 35 33
TEMP74  35 17 33  6 41 17 68 49 73 44 87 52 95 72 79 54 62 42 62 50 33 23 34 31
TEMP74  38 23 24  2 42 31 51 33 71 48 76 57 95 62 81 54 70 50 54 37 35 20 36 30
TEMP74  43 20 33 14 39 32 56 29 58 46 72 48 81 54 82 60 70 37 58 32 41 19 35 31
TEMP74  43 21 33 18 40 34 53 33 70 54 57 47 83 56 76 61 77 50 58 45 49 35 35 27
TEMP74  34 20 36 15 41 27 61 41 66 47 71 50 87 70 81 53 76 45 53 26 55 37 28 16
TEMP74  35 27 40 31 41 30 53 23 70 49 77 58 87 66 85 57 82 45 39 25 52 39 32 13
TEMP74  40 30 43 20 39 18 63 30 73 44 85 58 87 52 88 62 82 52 40 23 50 35 29 21
TEMP74  47 34 42 31 38 27 71 49 85 49 84 65 80 45 89 63 64 46 51 20 41 31 29 22
TEMP74  35 33 43 31 42 21 71 54 84 63 79 56 80 58 86 62 61 35 66 36 43 29 31 19
TEMP74  35 31 30 15 43 19 56 31 74 53 70 41 71 58 86 65 57 30 65 51 59 33 41 26
TEMP74  40 25 21  7 22  4 54 27 70 44 70 46 81 56 80 57 62 39 66 33 58 37 37 31
TEMP74  47 29 28  4 33  3 58 31 62 46 75 47 81 60 80 48 65 50 63 46 38 20 32 21
TEMP74  53 29 35 13 39 30 72 36 64 43 79 53 87 62 89 58 79 40 62 32 29 13 28 21
TEMP74  52 34 46 25 37 25 80 50 62 39 79 50 87 66 89 65 78 49 65 37 31 22 34 22
TEMP74  42 30 52 40 37 27 78 61 63 46 79 52 89 53 71 51 73 61 72 42 32 25 34 28
```

(continue)

TABLE Al (continued)

```
TEMP74  33 27       33 26 72 58 73 60 81 52 89 59 75 51 72 47 67 49 37 24 38 30
TEMP74  50 28       38 32 69 58 75 57 82 62 78 56 78 57 54 38 72 57 30 20 38 29
TEMP74  50 27       40 32       75 57       78 54 79 60       73 61       36 26
WIND74     90   130   170   140   105    50    71    64    43   140   116   232
WIND74     50   210   100   235   120    40    87    53    48   102    22   243
WIND74     30   100   110   135   120    30   112    38    66    18    40   174
WIND74    120   130    70   190    60    60    88    51    37    59    80    47
WIND74     50    60   250   190    80    60    78    82    10    90   102    21
WIND74     50   210    80   120   155    90    31    18    32    73    65    50
WIND74    190   160    80   140    85   140    39    29    28   121    54    24
WIND74     90    30   160   180    95    80    41    14    51    38    36   150
WIND74    120    60   130   130   115    70    55    43    33    51    20   196
WIND74     50   100   150    80    20   100    56    72    39    50    56   128
WIND74    110   240    70    90   145   140    73    83    61    48   103    37
WIND74    110    40   180   180   115    50    28    47    51    58   101    27
WIND74     80    60   130   225   185    90    37    49   106    72   123    16
WIND74    200   160    70   180   150    70    65    53    75   135    92    54
WIND74    250    80   100   305   175    50   105    39   105   103   215   201
WIND74    200   110    40    85    90   120    42    41    31    51    99   108
WIND74    180   160   220   110    50    95    31    52    82    50   121   144
WIND74     70   130   140   115    70    60    90    57    73    88   106   149
WIND74    130    50   130   105    80    47    78    51    65    32    58   160
WIND74    160   150    60    80    95    37    64    38    60    71   127    57
WIND74    210    50   130   145    30    85    35    41    60    40   279    22
WIND74    100   140   140   195    55    54    42    51    90   119    83    45
WIND74    150   320   220   250   130   101    52    38    20    50    89   202
WIND74    150    90   190   140   150    61    21    63    55    46   139    28
WIND74     80   110   150    70   130    59    37    27   115   107   122   152
WIND74     40   110   190    40    55    51    16    54   115    76    88   137
WIND74    230   150    60   100    30    49    61    80    65    66   138   113
WIND74    220    80   120   110    55    40    52    29    40    50    74   127
WIND74    100         170   150    40    41    80    30   140    69    59   105
WIND74    130          70    95    50   102   103    36   110    97    60   105
WIND74    230         150         100          83   104          64          30
RADI74    149    71   125   191   628   572   250   288   379   181   237    40
RADI74     82   170    90   484   413   453   274   310    41   209   214   180
RADI74    101   187   155   215   326   296   632   449   443   391    22    80
RADI74    196   265    19   169   492   610   376   587   458   278    41   182
RADI74    147   188   376   152   227   477   612   592   401   292    39    97
RADI74    105   101   299   578   364   402   654   525   416   164    32   134
RADI74    189   316   387   122   658   326   212   455   349   234   222    49
RADI74    151   392    33   361    71   343   563   318   411   222   226    74
RADI74    190   294   126   544   142   774   543   435   384   271   199   139
RADI74     74   143   375   515   565   260   307   341   255   330    71   164
RADI74    155   179   171   150   154   380   678   220   333   275    22    85
RADI74    253   262   415   292   307   646   674   472   230    46    35    39
RADI74    146   128   473   379   513   505   502   481   209   189    48    33
RADI74    150   270   406   175   212   412   548   553   302    52    71    43
```

(continue)

TABLE A1 (continued)

RADI74	99	341	90	255	382	415	600	524	382	280	93	22
RADI74	150	148	239	579	54	232	616	261	442	294	121	38
RADI74	101	317	457	574	170	209	368	286	306	284	175	79
RADI74	64	106	206	134	349	382	418	533	402	263	166	88
RADI74	148	72	302	616	605	285	521	486	386	157	41	74
RADI74	36	348	365	559	615	659	677	482	130	336	16	96
RADI74	16	236	346	200	525	500	619	475	312	316	72	65
RADI74	30	67	352	175	288	424	88	431	395	275	158	104
RADI74	81	255	265	150	644	287	310	355	397	127	139	163
RADI74	200	275	381	575	365	465	548	391	245	229	17	85
RADI74	250	370	646	200	382	637	246	508	309	211	162	89
RADI74	150	382	267	593	600	640	490	450	380	269	147	172
RADI74	75	297	131	422	275	668	558	392	322	248	52	71
RADI74	75	207	58	173	119	644	601	333	174	243	120	48
RADI74	101		103	315	211	621	596	462	177	34	181	65
RADI74	218		100	255	534	578	497	444	84	138	75	172
RADI74	196		100		290		542	481		165		38
DEWPT74	10	-24	27	40	53	50	50	58	48	34	47	32
DEWPT74	11	12	47	42	45	50	72	62	46	29	55	27
DEWPT74	0	5	55	53	45	57	67	57	41	27	45	22
DEWPT74	0	3	36	40	44	55	67	59	43	47	33	14
DEWPT74	-4	3	31	34	42	62	57	51	46	51	38	22
DEWPT74	18	-30	48	38	25	66	54	63	49	58	36	18
DEWPT74	10	2	34	34	25	68	61	59	54	33	38	34
DEWPT74	-2	4	33	26	37	68	67	62	60	37	45	22
DEWPT74	14	10	42	26	39	71	71	64	60	44	42	18
DEWPT74	17	22	27	26	38	60	68	60	66	47	44	24
DEWPT74	16	3	30	45	61	58	51	71	64	43	44	33
DEWPT74	-12	24	20	61	44	64	40	58	69	52	38	34
DEWPT74	9	29	8	59	41	64	68	62	50	48	31	33
DEWPT74	31	10	18	46	59	68	68	59	41	49	28	31
DEWPT74	31	1	36	33	48	67	57	61	52	37	25	33
DEWPT74	36	25	27	33	54	45	52	67	44	37	28	33
DEWPT74	12	21	21	40	54	50	62	61	56	34	36	21
DEWPT74	28	32	28	41	53	56	66	59	44	24	37	14
DEWPT74	32	31	26	35	54	67	58	60	59	33	48	27
DEWPT74	38	23	24	41	55	57	46	61	40	21	34	24
DEWPT74	30	26	20	53	67	66	49	61	36	25	31	26
DEWPT74	33	27	21	51	61	53	64	61	25	42	32	26
DEWPT74	30	-1	19	36	58	44	59	60	28	46	52	30
DEWPT74	27	0	3	25	45	45	59	53	34	51	36	30
DEWPT74	37	-1	17	31	46	49	64	59	36	37	21	24
DEWPT74	39	23	10	52	39	50	59	65	48	29	22	15
DEWPT74	35	26	21	43	48	49	46	58	50	33	29	30
DEWPT74	32	30	25	57	58	45	56	54	62	44	29	28
DEWPT74	33	0	31	64	64	44	51	53	40	56	18	33
DEWPT74	47	0	34	59	65	50	51	51	38	61	23	24
DEWPT74	27	0	34	0	58	0	52	43	0	62	0	32

(continue)

TABLE A1 (continued)

7401019																																				
7401021																																				
7401022																																				
7401023																																				
7401024																																				
7401025						1						1																								1
7401026																																				
7401027																																				
7401028																																				
7401039																																				
7401049																																				
7401059																																				
7401061																																				
7401062																																				
7401063																																				1
7401064													1																							
7401065												1																								1
7401066																																				
7401067																									1											
7401068																																				
7401071																																				
7401072																														1						
7401073																																				
7401074																																				
7401075																																				
7401076																																				
7401077																																				
7401078																																				
7401089																																				
7401091	1		1		1		1		1		1		1		1		1		1		1		1				1				1				1	
7401092			1					1						1																						
7401093																																				
7401094																																				
7401095																																				
7401096																																				
7401097																																				
7401098																																				
7401101																		1												1						1
7401102																							1													1
7401103																																				
7401104																																				
7401105																																				
7401106																																				
7401107																																				
7401108																							1													1
7401111			1				1				1				1				1				1				1				1				1	
7401112			1					1						1																						
7401113																																				

(continue)

TABLE A1 (continued)

7401114																																				
7401115																																				
7401116																																				
7401117																																				
7401118																	1					1				1		1		1		1		1		1
7401121						1								1							1															
7401122																																				
7401123																																				
7401124																																				
7401125																																				
7401126																																				
7401127																																				
7401128																																				
7401139																																				
7401149																																				
7401159																																				
7401169																																				
7401179																																				
7401189																																				
7401199																																				
7401201																																				
7401202																						2	3	3	4	2	1	1		1			1			1
7401203	1	3	3	2	2	2	3	1	2	2	3	2	6	4	6	7	3	2	2	1	1		1	1	1					1						
7401204	1				1				1																											
7401205																						1				1	1		1	1		1		1		
7401206				1			1		1	1		1		1		1			1								1	1			1		1			
7401207		1			1			1			1		1		1	1			1						1				1	1			1			
7401208	1				1		1					1	1		1				1		1		1		1	1		1			1				1	
7401211	1			1			1	1		1																										
7401212																																				
7401213			1		1		1	1																												
7401214																																				
7401215																																				
7401216																																				
7401217																																				
7401218																																				
7401221																																				
7401222																																				
7401223																																				
7401224																						1					1					1				
7401225		1								1									1								1					1				1
7401226				1		1	1		1	1								1					1					1		1	1				1	1
7401227	1	1	1		1	1		1		1		1		1	1		1		1	1		1			1	1		1			1	2		1	1	
7401228	1	1	1		1		1	1		1					1								1													
7401239																																				
7401249																																				
7401259																																				
7401261																																				

(continue)

TABLE A1 (continued)

```
7401262
7401263
7401264
7401265
7401266                                         1 2 2 3   1 1 1 1 1   1 2 2 2 2
7401267
7401268 6 5 3 1 1 1   1 1
7401271                                                                   1
7401272       1       1
7401273
7401274
7401275
7401276
7401277
7401278
7401281
7401282
7401283
7401284                                                           1   1   1   1
7401285
7401286     1   1   1           1   1       1
7401287
7401288
7401299
7401309
7401319
/*
```

TABLE A2. INPUT SEQUENCE FOR HYDROLOGY (WITHOUT SNOW), SEDIMENT, AND PESTICIDE SIMULATION WITH METEOROLOGIC DATA

```
//HARL7508 JOB 'A19$X2,444,.10,40','J7508 DAVIS '
/*JOBPARM HOLD=JOB
//JOBLIB DD DSNAME=WYL.X2.A19.HD7508.ARMLM.DP100677,
// UNIT=DISK,VOL=SER=PUB005,DISP=(OLD,KEEP)
//STEP1 EXEC PGM=ARM
//SYSPRINT DD SYSOUT=A
//FT06F001 DD SYSOUT=A
//FT05F001 DD *
P-2: PESTICIDE RUN USING LITERATURE PARAQUAT VALUES & SZDPTH=0.125
PARAQUAT APPLIED: 1973, 1974, & 1975
HYCAL=CALB
INPUT=ENGL
OUTPUT=ENGL
PRINT=INTR
SNOW=NO
PEST=YES
NUTR=NO
ICHECK=OFF
DISK=NO
 &CNTL  INTRVL= 5, HYMIN=  0.0500, AREA=  3.2  &END
 &STRT BGNDAY= 1, BGNMON=12, BGNYR= 1973   &END
 &ENDD ENDDAY=14, ENDMON= 2, ENDYR= 1974     &END
 &LND1 UZSN= 0.500, UZS=  1.000, LZSN= 18.00, LZS= 24.00     &END
 &LND2 L=100.,SS= 0.025,NN= 0.2000,A= 0.0000,EPXM=0.1200,PETMUL=1.000  &END
 &LND3 K3=0.30,0.30,0.30,0.40,0.40,0.50,0.70,0.80,0.60,0.50,0.40,0.30 &END
 &LND4 INFIL=0.10,INTER=0.70,IRC=0.00,K24L= 1.00,KK24= 0.60,K24EL=0.00 &END
 &LND5 SGW=0.00,GWS=0.00,KV=0.00,ICS=0.00,OFS=0.00,IFS=0.000           &END
 &CROP COVPMO=0.6,0.6,0.6,0.6,0.0,0.15,0.60,0.85,0.75,0.60,0.60,0.60 &END
 &MUD1 TIMTIL= 115,114,0,0,0,0,0,0,0,0,0,0    &END
 &MUD2 YRTIL=   74,75,0,0,0,0,0,0,0,0,0,0    &END
 &MUD3 SRERTL= 1.00,2.00,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0       &END
 &SMDL JRER=1.9,KRER=0.08,JSER=1.70,KSER=0.5,SRERI=2.000,SCMPAC=0.02    &END
PESTICIDE
APMODE=SURF
DESORP=YES
 &PSTR PSSZ=0.0, PSUZ=0.0, PSLZ=0.0, PSGZ=   0.0    &END
 &PST1 TIMAP= 131, 119, 141, 0, 0, 0, 0, 0, 0, 0, 0, 0     &END
 &PST2 YEARAP=  73,74,75,0,0,0,0,0,0,0,0,0    &END
 &PST3 SSTR=   2.10, 2.20, 1.70, 0.0, 8*0.0    &END
 &AMDL CMAX=1.0E-5,DD=0.0003,K=120.0,N=2.0000,NP=4.600     &END
 &DEGD DDG=131,119,141,0,0,0,0,0,0,0,0,0            &END
 &DEGY YDG= 73,74,75,0,0,0,0,0,0,0,0,0  &END
 &DEGR KDG= 0.002,0.002,0.002,0.0      &END
 &DPTH SZDPTH=.125,UZDPTH=6.125,BDSZ=99.9,BDUZ=99.9,BDLZ=99.9,UZF=3.,
          LZF=1.5 &END
 EVAP73        18    74    60    29    13   266   131   103    19    41    90    68
 EVAP73        18    90   170    29    13    70   163    96    63    69    72    68
 EVAP73        18    60    43    30    14    65   140    53   189    97    48    47
```

(continue)

TABLE A2 (continued)

```
EVAP73     0    61    43    60     4    70   156   162   124   104    48    52
EVAP73    35    61    43   112   202   171   145    34   115   117   114    47
EVAP73    28    82    71    15    99     8   185   122    24   138    54    42
EVAP73    28   121     4    15   100    72    87    65   161   124    12    31
EVAP73    28    69    41    15    34    70   145   105    92    90     0    57
EVAP73    28     7    35    15   135    37    62   130   145   117    78    36
EVAP73    28    20    20    15   210   108   185    36   218   159    72    10
EVAP73    28    21    20    16   202    68   175   139   185    76    60    57
EVAP73    28    21    21    16   219   142   133   162   145    34    48    36
EVAP73    28    16   123   113   145   132   185     4    99   110    48    57
EVAP73    28    54   123   113   176    90   154    72   211   117    54    36
EVAP73    27    46   132   113   192   156   246   208   125    76    24    36
EVAP73    33    47   103   113   222   121   140   115   158    83    24   104
EVAP73    19    45    61     1   171   160    89   123   191    90    60    73
EVAP73    41    45    61    88   173    70    58    92   139   110   120    47
EVAP73    41    46    61    88   159    72    80    72   112   117    66    57
EVAP73    54    46    61    88    72   161    46   130   119   104    24    73
EVAP73    54    81   112    88   103    84   168   205    73    83    48   104
EVAP73    55    83    44    88   198   149   129   178    79    83    36   109
EVAP73   118   101   104    88   154   183   136   143   132    83    66    99
EVAP73    32    45    87    13   232    62   141   122   152    77    36    83
EVAP73    24    46    87    13   153   262    71   112   112    71    30    10
EVAP73    24    46    87    19   114   109    65   136    92    65    48    42
EVAP73    24    28    72   332    90   126    27    52    33    59    24    68
EVAP73    25    60    86    58   152    59    43   170    66    53    78    36
EVAP73    25          50    58     3   137   148    37    79    48    54    16
EVAP73    91          31    58   153   213   155   249   165    69   204    47
EVAP73    17          31         198         103    38          14          68
 7312019
 7312029
 7312039
 7312041
 7312042
 7312043
 7312044
 7312045
 7312046
 7312047           2 3 3
 7312048
 7312059
 7312061   1 1 1 1 1 1 1 1 2 3       1     1                           1 1
 7312062               1 2       1 1 1 2 5   1 31311 9 8 5 2 3 9 7 2 2 2 4 410 5
 7312063 5 5 3 2 2 2 1 1   1 1 1   1   1   1
 7312064
 7312065
 7312066
 7312067
 7312068
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(continue)

TABLE A2 (continued)

7312079																																				
7312089																																				
7312099																																				
7312109																																				
7312119																																				
7312129																																				
7312139																																				
7312149																																				
7312151																																				
7312152																																				
7312153																													1	1		1	1	1	3	2
7312154	3	2	3	2	2	3	3	2	3	2	3	2	3	2	3	2		1			1					1					1					1
7312155		1		1																																
7312156																																				
7312157																											1				1				1	
7312158			1			1				1				1				1																		
7312161																																				
7312162																																				
7312163																																				
7312164																																				
7312165																																				
7312166																																				
7312167	1	1	1		1	1				1				1				1						1						1						
7312168																																				
7312179																																				
7312189																																				
7312199																																				
7312201																																				
7312202																																				
7312203																																			1	1
7312204	2	1		1		1			1		1			1	1	1		1		1		1		1		1										
7312205													1	1	1	1	1	5	8	7	5	4	5	2	9	4	1	1		1			1			1
7312206																																				
7312207																																				
7312208																																				
7312219																																				
7312229																																				
7312239																																				
7312249																																				
7312251																																				
7312252																																				
7312253																																				
7312254																																				
7312255																																				
7312256																																				
7312257																																				
7312258																																				1
7312261										1											1													1		

(continue)

TABLE A2 (continued)

```
7312262               1         1 1 2             1 1 1 1 1 2 4 2 2 2 2 3 5 2 2
7312263 2     1     1     1   1   1                   1 1 1 1 1 2 3 3 2 1 2 1 1
7312264
7312265               1   1   1   1 1
7312266
7312267
7312268
7312279
7312289
7312299
7312301
7312302
7312303
7312304                         1 1 1 2 1 1 1   1
7312305
7312306                             4 2 5 4 3 7 1           1
7312307         1                         1 1 1   1 1 1 1 1 1 1   1 2   1 1 814
7312308                         1 1   1 3                       1
7312311                 1 3 1 1 2 1
7312312
7312313
7312314
7312315
7312316     1 1 1 1   1             1 1   1   1   2 4 6 8 2 2 62128 2 5 4 1 2 2
7312317 2 4 1 2 1         1           1 1 2 1 1 2 3 4 2 1 1 1 1 1 1 1 1 1 2 2 2
7312318 1 1 1 1 2 3 2 2 2 3 2 2 2 2 1 1 2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1
EVAP74      92    76   126    98   140    77   206    80   177   124    66    55
EVAP74      86    69   141    84   158    34   120   181   155   110    66    55
EVAP74      86    88   126   252   176    38   217   103    57   110    66    55
EVAP74      16    69   111   175   201   237   174    70   172   110    66    35
EVAP74       5   158   148   217    95   120   109   113   131   110    66    35
EVAP74      92   132     7   175    22   157    28   175     7   110    54    35
EVAP74     108    94     0   252   169   192    84   185    20   110    54    35
EVAP74      43    82   155   189   119     0   120     0    32   110    54    35
EVAP74      11    69   111   196   123   140   102    49    34    76    54    35
EVAP74       5    94   126   133   164   203   210   136    63    76    54    35
EVAP74      43   132   118   140   144    45   217   213    84    76    54    35
EVAP74      86    50   148   140   171   325   150    76   125    76    54    71
EVAP74      81    50   133   161   199   202   151    61   100    76    54    71
EVAP74      86    94   170   147   190   156    77   116    92    76    24    72
EVAP74      59    69   170   175   205    72    85   209    26    76    24    72
EVAP74      22    69   141     7   119   260    94   195    98    41    24    72
EVAP74      43    19   104    14   187   195   197    71    66    41    24    72
EVAP74      27    50    89   140    93   207    92   144    46    41    24    72
EVAP74      38   126   141    98   271    92   510   224   117    41    24   120
EVAP74      22    69    81   140   145   110   133   206   101    41    78   120
EVAP74      49   107    89    49    57   211   158   301    11    41    78   120
EVAP74      98    69   111   105    68   271   163   132    95    41    78   120
```

(continue)

TABLE A2 (continued)

```
EVAP74      54   101   104   210   210   276    82   215    95    76    78   120
EVAP74      22    69    37   175   103   211    13   126   110    76    78   120
EVAP74       5    82   118   147   188   171   236   147    11    76    78   120
EVAP74      22   113    30   147   239   122    44   146    37    76    78   120
EVAP74      32   158    59   203     4   365    20   130    31    76    66    10
EVAP74      43    82    59   168   171   530    16   123    30    76    66    10
EVAP74      65         133   196   195   134   136   156   104    76    66    10
EVAP74      38          15   196   147   181   140   207   137    76    66    10
EVAP74      43         185         156         300    76          76          10
 7401011             1 1 5 1 1                                     1     1     1
 7401012
 7401013
 7401014
 7401015
 7401016
 7401017
 7401018
 7401021
 7401022
 7401023
 7401024
 7401025
 7401026
 7401027                                                     5 3 3 5
 7401028
 7401031
 7401032
 7401033
 7401034
 7401035
 7401036
 7401037                                                                       6
 7401038 5 3   1 2 3 2 2 1     1 1   1 1   1 1 1   1 1 1 1 1
 7401041
 7401042
 7401043
 7401044
 7401045
 7401046                                                         1 2 2 3       1
 7401047           1     1   1 1 4
 7401048
 7401059
 7401069
 7401071                                        10 1 1 1   1   1   1
 7401072       1                       1 1 1     1     1       1       1 2 4
 7401073 1   1       1         1
 7401074
 7401075
```

(continue)

TABLE A2 (continued)

7401076																																				
7401077																																				
7401078																																				
7401089																																				
7401099																																				
7401109																																				
7401111																																				
7401112																																				
7401113																																				
7401114																						1	2	3	2											
7401115																																				
7401116																																				
7401117																																				
7401118																																				
7401129																																				
7401139																																				
7401149																																				
7401159																																				
7401169																																				
7401179																																				
7401189																																				
7401199																																				
7401201																																				
7401202																																				
7401203																															1		1	1		1
7401204				1					1	1																										
7401205																																				
7401206																																				
7401207																			1	2	1	3	3	2	1	1	1	1	1	1	1	1	1	1	1	2
7401208	2	1	1	1	1	1	1	1		1	1	1		1												1		1	1	1	2	2	2	1	1	1
7401211		1	1	3	4	3	3	4	5	3		1		1																						
7401212																																				
7401213																																				
7401214																																				
7401215																																				
7401216																																				
7401217																																				
7401218																																				
7401229																																				
7401239																																				
7401241																			1	2	2	1	1	1		1		1								
7401242																																				
7401243																																	5		1	1
7401244																			3	2	1	1														
7401245																																				
7401246																																				
7401247																																				
7401248																																				

(continue)

TABLE A2 (continued)

7401259																																				
7401269																																				
7401279																																				
7401281																																				
7401282																																				
7401283																																				
7401284																																				
7401285																																				
7401286									1	1	1	1	1																				1				
7401287			1								1	2																								
7401288																																				
7401291																																				
7401292																																				
7401293																																				
7401294																																				
7401295												1													1	1		1	1	1	1	1	1	1	1	1
7401296		1		1	1	1	1	1		1	1		1		1		1		1		1		1													
7401297																																				
7401298																																				
7401309																																				
7401319																																				
7402019																																				
7402029																																				
7402039																																				
7402049																																				
7402059																																				
7402061																																				
7402062																																				
7402063																																				
7402064															4	4	1		1	1	1	2	1	1	1											
7402065				1																				1				1	1	1		1	1	1	1	1
7402066	1							1				1	1	2	1	1	2	3	3	4	3	3	2	1	4	14	6	5	3	2	5	5	5	5	3	2
7402067	3	2	3	2	1	9	3	2	2	2	2	2	1	1	1	1				1					1					1				1		
7402068	1				1			1			1	1		1		1		1		1		1		1		1		1		1						
7402071																																				
7402072																																				
7402073																																				
7402074																																				
7402075																													1	2	1		1	2	2	1
7402076				1																																
7402077																																				
7402078																																1		1		1
7402081		1					1					1						1						1						1						
7402082																																				
7402083																																				
7402084																																				
7402085																																				
7402086																																				

(continue)

TABLE A2 (continued)

```
 7402087
 7402088
 7402099
 7402109
 7402119
 7402129
 7402139
 7402141
 7402142
 7402143
 7402144
 7402145
 7402146                                                               1       1
 7402147       1       1       1           1     1 1 1 1 2 2 2 2 1 1   1
 7402148   1             1             1               1       1       1   1
/*
```

TABLE A3. PARAMETER INPUT SEQUENCE FOR HYDROLOGY (WITH SNOW), SEDIMENT, AND NUTRIENT SIMULATION

```
//HARL7508 JOB 'A19$X2,444,.05,40','SNOW NUTR PROD'
/*JOBPARM HOLD=JOB
//JOBLIB DD DSNAME=WYL.X2.A19.HD7508.ARMLM.DP100677,
// UNIT=DISK,VOL=SER=PUB005,DISP=(OLD,KEEP)
//STEP1 EXEC PGM=ARM
//SYSPRINT DD SYSOUT=A
//FT06F001 DD SYSOUT=A
//FT05F001 DD *
MICHIGAN P6 SNOW SAMPLE
HYDROLOGY,SEDIMENT, AND NUTRIENTS
HYCAL=PROD
INPUT=ENGL
OUTPUT=ENGL
PRINT=DAYS
SNOW=YES
PEST=NO
NUTR=YES
ICHECK=ON
DISK=NO
 &CNTL  INTRVL= 5, HYMIN=  0.010, AREA=    1.98   &END
 &STRT BGNDAY=20, BGNMON= 1, BGNYR= 1974   &END
 &ENDD ENDDAY=21, ENDMON= 1, ENDYR= 1974        &END
 &LND1 UZSN= 0.200, UZS=  0.500, LZSN=  9.00, LZS= 11.0   &END
 &LND2 L= 60.,SS= 0.060,NN= 0.2000,A= 0.0000,EPXM=0.1200,PETMUL=1.000  &END
 &LND3 K3=0.20,0.20,0.20,0.20,0.30,0.30,0.50,0.45,0.40,0.30,0.20,0.20 &END
 &LND4 INFIL=0.03,INTER=0.80,IRC=0.00,K24L= 1.00,KK24= 0.00,K24EL=0.00 &END
 &LND5 SGW=0.00,GWS=0.00,KV=0.00,ICS=0.00,OFS=0.00,IFS=0.000   &END
SNOWPRINT=NO
 &SNO1 RADCON=1.0,CCFAC=1.00,SCF=1.40,ELDIF=0.0,IDNS= 0.14,F= 0.0 &END
 &SNO2 DGM=0.0,WC=0.03,MPACK=1.0,EVAPSN=0.40,MELEV= 892.,TSNOW=32.00 &END
 &SNO3 PACK= 0.0,DEPTH=  0.0 &END
 &SNO4 PETMIN= 35.0,PETMAX= 40.0,WMUL= 1.0,RMUL= 1.00,KUGI= 0.0 &END
 &CROP COVPMO=0.0,0.0,0.0,0.0,0.0,0.05,0.55,0.90,0.90,0.80,0.0,0.0 &END
 &MUD1 TIMTIL= 140,136,0,0,0,0,0,0,0,0,0,0      &END
 &MUD2 YRTIL=   74,75,0,0,0,0,0,0,0,0,0,0   &END
 &MUD3 SRERTL= 1.00,0.80,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0      &END
 &SMDL JRER=2.2,KRER=0.15,JSER=1.40,KSER=0.5,SRERI=1.000,SCMPAC=0.001   &END
NUTRIENT
 &NUTRIN  TSTEP=  60, NAPPL=   2,TIMHAR= 275   &END
 &PLANTU ULUPTK=0.0,0.0,0.0,0.0,0.0,1.0,0.5,0.05,0.0,0.0,0.0,0.0     &END
 &PLANTL LZUPTK=0.0,0.0,0.0,0.0,0.0,0.30,0.75,0.055,0.0,0.0,0.0,0.0   &END

REACTION RATES
NITROGEN
SURFACE
  3.00   0.0      0.25    0.015    0.0      0.0      5.0     0.75
UPPER ZONE
  1.25   0.05      0.40   0.0015   0.0      0.0     0.75      0.3
```

(continue)

TABLE A3 (continued)

```
LOWER ZONE
   0.7      0.0     0.090  0.0015    0.0      0.0     1.0      0.4
GROUNDWATER
   0.0      0.0      0.0    0.0      0.0      0.0      0.0      0.0
TEMPERATURE COEFFICIENTS
  1.05    1.07     1.07    1.07     1.07     1.07    1.05     1.05

PHOSPHORUS
SURFACE
 0.015   0.0      0.01    1.00      0.01
UPPER ZONE
 0.0015  0.0      2.10    0.5      0.006
LOWER ZONE
 0.0015  0.0      1.70    0.5      0.005
GROUNDWATER
   0.0        0.0     0.0     0.0      0.0
TEMPERATURE COEFFICIENTS
   1.07    1.07    1.07    1.05    1.05
END

INITIAL
NITROGEN
SURFACE
  69.4    0.20     0.91    0.30     0.0      0.0
UPPER ZONE
 440.0    4.29    10.00    19.9     0.0      0.0
LOWER ZONE
  1488.    20.0     50.0    152.0   0.0      0.0
GROUNDWATER
  0.0      0.0      0.0     0.0      0.0      0.0

PHOSPHORUS
SURFACE
 40.5      1.3      2.6     0.0
UPPER ZONE
  220.     1.36    111.64    0.0
LOWER ZONE
  800.      20.0   200.0     0.0
GROUNDWATER
  0.0      0.0      0.0     0.0

CHLORIDE
SURFACE
  0.00
UPPER ZONE
 130.0
LOWER ZONE
  00.0
```

(continue)

TABLE A3 (continued)

```
GROUNDWATER
  0.0
END

APPLICATION  136
NITROGEN
SURFACE
     0.0    0.3    1.0     1.3     0.0     0.0
UPPER ZONE
     0.0   29.2    0.0    29.2     0.0     0.0

PHOSPHORUS
SURFACE
     0.0    3.65    0.30     0.0
UPPER ZONE
     0.0   112.0    0.0      0.0

CHLORIDE
SURFACE
     5.8
UPPER ZONE
  134.2
END

APPLICATION  176
NITROGEN
SURFACE
     0.0   14.2     0.2    14.2     0.0     0.0
UPPER ZONE
  0.0    14.1     0.0    14.3     0.0     0.0

PHOSPHORUS
SURFACE
     0.0    0.0     0.0     0.0
UPPER ZONE
     0.0    0.0     0.0     0.0

CHLORIDE
SURFACE
     0.0
UPPER ZONE
     0.0
END
 &LZTP  LZTEMP=38.2,36.6,37.1,40.1,48.5,56.5,62.4,65.1,64.5,58.7,51.3,44.3  &END
 &RETP ASZT=24.27,BSZT=0.630,AUZT=0.0,BUZT=1.0  &END
 &DPTH SZDPTH=.125,UZDPTH=3.125,BDSZ=63.7,BDUZ=72.4,BDLZ=99.0,UZF=5.,LZF=1. &END
```

TABLE A4. PARAMETER INPUT SEQUENCE FOR HYDROLOGY (WITHOUT SNOW) AND SEDIMENT SIMULATION WITH RUNOFF AND SEDIMENT WRITTEN TO DISK

```
//HARL7508 JOB 'A19$X2,444,.25,40','DISK ON TEST'
/*JOBPARM HOLD=JOB
//JOBLIB DD DSNAME=WYL.X2.A19.HD7508.ARMLM.DP100677,
// UNIT=DISK,VOL=SER=PUB005,DISP=(OLD,KEEP)
//STEP1 EXEC PGM=ARM
//SYSPRINT DD SYSOUT=A
//FT06F001 DD SYSOUT=A
//FT10F001 DD DSN=WYL.X2.A19.ARM.TEST.LSRO,DISP=(NEW,KEEP),
//  SPACE=(TRK,(10,3),RLSE),VOL=SER=PUB005,UNIT=DISK,
//  DCB=(RECFM=VBS,LRECL=516,BLKSIZE=2068)
//FT11F001 DD DSN=WYL.X2.A19.ARM.TEST.EROS,DISP=(NEW,KEEP),
//  SPACE=(TRK,(10,3),RLSE),VOL=SER=PUB005,UNIT=DISK,
//  DCB=(RECFM=VBS,LRECL=516,BLKSIZE=2068)
//FT05F001 DD *
NO SNOW ****TEST**** DISK RUN
NO PESTICIDES OR NUTRIENTS
HYCAL=CALB
INPUT=ENGL
OUTPUT=ENGL
PRINT=INTR
SNOW=NO
PEST=NO
NUTR=NO
ICHECK=ON
DISK=YES
IDEBUG=ON
RUNOFF
TEST DISK OPTION
DSNFLO=10
SEDIMENT
TEST DISK OPTION
DSNERS=11
ENDDISK
 &CNTL  INTRVL= 5, HYMIN=  0.010, AREA=    1.98   &END
 &STRT BGNDAY=21, BGNMON= 8, BGNYR= 1975   &END
 &ENDD ENDDAY=21, ENDMON= 8, ENDYR= 1975                              &END
 &LND1 UZSN= 0.200, UZS=  0.301, LZSN=  9.00, LZS=  8.736             &END
 &LND2 L= 60.,SS= 0.060,NN= 0.2000,A= 0.0000,EPXM=0.1200,PETMUL=1.000  &END
 &LND3 K3=0.20,0.20,0.20,0.20,0.30,0.30,0.50,0.45,0.40,0.30,0.20,0.20 &END
 &LND4 INFIL=0.03,INTER=0.80,IRC=0.00,K24L= 1.00,KK24= 0.00,K24EL=0.00 &END
 &LND5 SGW=0.00,GWS=0.00,KV=0.00,ICS=0.00,OFS=0.00,IFS=0.000          &END
 &CROP COVPMO=0.0,0.0,0.0,0.0,0.0,0.05,0.40,0.75,0.85,0.80,0.0,0.0 &END
 &MUD1 TIMTIL= 140,136,0,0,0,0,0,0,0,0,0,0                            &END
 &MUD2 YRTIL=   74,75,0,0,0,0,0,0,0,0,0,0                              &END
 &MUD3 SRERTL= 1.00,1.00,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0       &END
 &SMDL JRER=2.2,KRER=0.15,JSER=1.40,KSER=0.5,SRERI=0.893,SCMPAC=0.01    &END
```

APPENDIX B

SAMPLE OUTPUT FROM THE ARM MODEL

TABLES

B1 Output Heading - Hydrology (without snow), Sediment, and Pesticide Simulation

B2 Output Heading - Hydrology (with snow), Sediment, and Nutrient Simulation

B3 Monthly Summary - Hydrology (without snow), Sediment, and Pesticide Simulation

B4 Monthly Summary - Hydrology (with snow), Sediment, and Nutrient Simulation

B5 Daily Production Run Summary (HYCAL=PROD) - Hydrology (without snow), Sediment, and Nutrient Simulation

B6 Daily Production Run Summary (HYCAL=PROD) - Hydrology (with snow), Sediment, and Nutrient Simulation

B7 Storm Event Calibration Run Output (HYCAL=CALB) - Hydrology and Sediment Simulation

B8 Storm Event Calibration Run Output (HYCAL=CALB) - Hydrology, Sediment, and Pesticide Simulation

B9 Storm Event Calibration Run Output (HYCAL=CALB) - Hydrology, Sediment, and Nutrient Simulation

B10 Daily Snowmelt Output (SNOWPRINT=YES) - Calibration Run, English Units

B11 Daily Snowmelt Output Definitions - Calibration Run, English Units

TABLE B1. OUTPUT HEADING - HYDROLOGY (WITHOUT SNOW), SEDIMENT, AND PESTICIDE SIMULATION

```
                 THIS IS A PRODUCTION RUN FOR PESTICIDES

                        WATERSHED:     P-2: PESTICIDE RUN USING LITERATURE PARAQUAT VALUES & SZDPTH=0.125

                        CHEMICAL:      PARAQUAT APPLIED: 1973, 1974, & 1975

                        INPUT UNITS:   ENGLISH

                        OUTPUT UNITS:  ENGLISH

                        PRINT INTERVAL: EACH DAY

                        SNOWMELT NOT PERFORMED

                        ADSORPTION AND DESORPTION ALGORITHMS USED

                        PESTICIDE APPLICATION:  SURFACE-APPLIED


LINE PRINTER OUTPUT ONLY

INTRVL=  5           HYMIN=   0.0500       AREA=     3.2000

BGNDAY= 11           BGNMON=  5            BGNYR= 1973

ENDDAY= 26           ENDMON=  5            ENDYR= 1973


UZSN=   0.5000       UZS=   1.0000         LZSN=  18.0000        LZS=  24.0000

L= 100.0000          SS=   0.0250          NN=    0.2000         A=    0.0              EPXM=   0.1200        PETMUL=  1.

K3 = 0.30  0.30  0.30  0.40  0.40  0.50  0.70  0.80  0.60  0.50  0.40  0.30

INFIL=   0.1000      INTER=   0.7000       IRC=    0.0           K24L=   1.0000         KK24=   0.6000        K24EL=   0.

SGW=   0.0           GWS=   0.0            KV=    0.0            ICS=    0.0            OFS=    0.0           IFS=    0.0
```

(continue)

TABLE B1 (continued)

```
COVPMO= 0.60  0.60  0.60  0.60  0.0   0.15  0.60  0.85  0.75  0.60  0.60  0.60

TIMTIL= 115  114    0    0    0    0    0    0    0    0    0    0
YRTIL = 74   75    0    0    0    0    0    0    0    0    0    0
SRERTL=  1.000   2.000   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

JRER= 1.9000         KRER= 0.0800         JSER= 1.7000         KSER= 0.5000         SRERI= 2.0000         SCMPAC= 0.0200


PSSZ=   0.0             PSUZ=  0.0             PSLZ=  0.0             PSGZ=   0.0

TIMAP=  131  119  141    0    0    0    0    0    0    0    0    0
YEARAP=  73   74   75   75   75   75   75   75   75   75   75   75
SSTR=    2.100   2.200   1.700   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

CMAX= 0.000010         DD= 0.000300          K= 120.0000          N=   2.0000          NP=   4.6000

DDG= 131  119  141    0    0    0    0    0    0    0    0    0
YDG=  73   74   75   75   75   75   75   75   75   75   75   75
KDG= 0.002  0.002  0.002  0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0


HYCAL=PROD  INPUT=ENGL  OUTPUT=ENGL  PRINT=DAYS  SNOW=NO   PEST=YES   NUTR=NO   ICHECK=OFF

APMODE=SURF  DESORP=YES


SOIL ZONES DEPTHS AND BULK DENSITIES
SZDPTH=   0.1250       UZDPTH=   6.1250       BDSZ=  99.9000       BDUZ=  99.9000       BDLZ=  99.9000
LEACHING FACTORS
UZF =  3.000       LZF =  1.500
```

TABLE B2. OUTPUT HEADING - HYDROLOGY (WITH SNOW), SEDIMENT, AND NUTRIENT SIMULATION

```
                         THIS IS A PRODUCTION RUN FOR NUTRIENTS


                                WATERSHED:      MICHIGAN P6 SNOW SAMPLE

                                CHEMICAL:       HYDROLOGY,SEDIMENT, AND HYDROLOGY

                                INPUT UNITS:    ENGLISH

                                OUTPUT UNITS:   ENGLISH

                                PRINT INTERVAL: EACH DAY

                                SNOWMELT CALCULATIONS PERFORMED




LINE PRINTER OUTPUT ONLY

INTRVL= 5              HYMIN=   0.0100        AREA=     1.9800

BGNDAY= 20             BGNMON=  1             BGNYR= 1974

ENDDAY= 21             ENDMON=  1             ENDYR= 1974


UZSN=   0.2000         UZS=   0.5000          LZSN=   9.0000         LZS=  11.0000

L=  60.0000            SS=   0.0600           NN=   0.2000           A=   0.0               EPXM=   0.1200         PETMUL=  1.

K3 = 0.20  0.20  0.20  0.20  0.30  0.30  0.50  0.45  0.40  0.30  0.20  0.20

INFIL=   0.0300        INTER=   0.8000        IRC=   0.0             K24L=   1.0000         KK24=   0.0            K24EL=   0.

SGW=   0.0             GWS=   0.0             KV=   0.0              ICS=   0.0             OFS=   0.0             IFS=   0.0


RADCON=   1.0000       CCFAC=   1.0000        SCF=   1.4000          ELDIF=   0.0           IDNS=   0.1400         F=   0.0

DGM=   0.0             WC=   0.0300           MPACK=   1.0000        EVAPSN=   0.4000       MELEV=     892.        TSNOW=  32.

PACK=   0.0            DEPTH=   0.0

PETMIN=  35.0000       PETMAX=  40.0000       WMUL=   1.0000         RMUL=   1.0000         KUGI=   0.0
```

(continue)

TABLE B2 (continued)

```
COVPMO= 0.0   0.0   0.0   0.0   0.0   0.05  0.55  0.90  0.90  0.80  0.0   0.0

TIMTIL= 140  136    0     0     0     0     0     0     0     0     0     0
YRTIL = 74   75    0     0     0     0     0     0     0     0     0     0
SRERTL=  1.000   0.800   0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

JRER= 2.2000        KRER= 0.1500        JSER= 1.4000        KSER= 0.5000        SRERI= 1.0000        SCMPAC= 0.0010


HYCAL=PROD  INPUT=ENGL  OUTPUT=ENGL  PRINT=DAYS  SNOW=YES   PEST=NO    NUTR=YES   ICHECK=ON

SNOWPRINT=NO


NUTRIENT



                              NUTRIENT SIMULATION INFORMATION



   TIME STEP FOR TRANSFORMATIONS =     60 MIN
   NUMBER OF NUTRIENT APPLICATIONS =  2
   DATE OF PLANT HARVESTING =  273
   FRACTION OF MAXIMUM MONTHLY UPTAKE
      UPPER LAYERS =  0.0   0.0   0.0   0.0   0.0   1.000 0.500 0.050 0.0   0.0   0.0   0.0
      LOWER ZONE =    0.0   0.0   0.0   0.0   0.0   0.300 0.750 0.055 0.0   0.0   0.0   0.0

 NITROGEN REACTION RATES       K1       KD       KPL      KAM      KIM      KKIM     KSA      KAS
      SURFACE               3.0000   0.0      0.2500   0.0150   0.0      0.0      5.0000   0.7500
      UPPER ZONE            1.2500   0.0500   0.4000   0.0015   0.0      0.0      0.7500   0.3000
      LOWER ZONE            0.7000   0.0      0.0900   0.0015   0.0      0.0      1.0000   0.4000
      GROUNDWATER           0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0
   TEMPERATURE COEF.        1.050    1.070    1.070    1.070    1.070    1.070    1.050    1.050

 PHOSPHORUS REACTION RATES     KM       KIM      KPL      KSA      KAS
      SURFACE               0.0150   0.0      0.0100   1.0000   0.0100
      UPPER ZONE            0.0015   0.0      2.1000   0.5000   0.0060
      LOWER ZONE            0.0015   0.0      1.7000   0.5000   0.0050
      GROUNDWATER           0.0      0.0      0.0      0.0      0.0
   TEMPERATURE COEF.        1.070    1.070    1.070    1.050    1.050
```

(continue)

TABLE B2 (continued)

```
NUTRIENTS - LB/AC            ORG-N   NH3-S   NH3-A   NO3+NO2    N2  PLNT-N   ORG-P   PO4-S   PO4-A  PLNT-P       CL
   INITIAL STORAGES

   SURFACE LAYER

      AVERAGE                  69.   0.200   0.910   0.300   0.0     0.0       41.   1.300   2.600   0.0      0.0
            BLOCK 1            69.   0.200   0.910   0.300   0.0     0.0       41.   1.300   2.600   0.0      0.0
            BLOCK 2            69.   0.200   0.910   0.300   0.0     0.0       41.   1.300   2.600   0.0      0.0
            BLOCK 3            69.   0.200   0.910   0.300   0.0     0.0       41.   1.300   2.600   0.0      0.0
            BLOCK 4            69.   0.200   0.910   0.300   0.0     0.0       41.   1.300   2.600   0.0      0.0
            BLOCK 5            69.   0.200   0.910   0.300   0.0     0.0       41.   1.300   2.600   0.0      0.0

   UPPER ZONE

      AVERAGE                 440.   4.290  10.000  19.900   0.0     0.0      220.   1.360 111.640   0.0    130.000
            BLOCK 1           440.   4.290  10.000  19.900   0.0     0.0      220.   1.360 111.640   0.0    130.000
            BLOCK 2           440.   4.290  10.000  19.900   0.0     0.0      220.   1.360 111.640   0.0    130.000
            BLOCK 3           440.   4.290  10.000  19.900   0.0     0.0      220.   1.360 111.640   0.0    130.000
            BLOCK 4           440.   4.290  10.000  19.900   0.0     0.0      220.   1.360 111.640   0.0    130.000
            BLOCK 5           440.   4.290  10.000  19.900   0.0     0.0      220.   1.360 111.640   0.0    130.000

   LOWER ZONE

      STORAGE                1488.  20.000  50.000 152.000   0.0     0.0      800.  20.000 200.000   0.0      0.0

   GROUNDWATER

      STORAGE                   0.   0.0     0.0     0.0     0.0     0.0        0.   0.0     0.0     0.0      0.0

   TOTAL NITROGEN IN SYSTEM =      2255.000  LB/AC
   TOTAL PHOSPHORUS IN SYSTEM =    1397.400  LB/AC
   TOTAL CHLORIDE IN SYSTEM =       130.000  LB/AC


NUTRIENTS - LB/AC            ORG-N   NH3-S   NH3-A   NO3+NO2    N2  PLNT-N   ORG-P   PO4-S   PO4-A  PLNT-P       CL

APPLICATION FOR DAY 136

   SURFACE LAYER

      AVERAGE                   0.   0.300   1.000   1.300   0.0     0.0        0.   3.650   0.300   0.0      5.800
            BLOCK 1             0.   0.300   1.000   1.300   0.0     0.0        0.   3.650   0.300   0.0      5.800
            BLOCK 2             0.   0.300   1.000   1.300   0.0     0.0        0.   3.650   0.300   0.0      5.800
            BLOCK 3             0.   0.300   1.000   1.300   0.0     0.0        0.   3.650   0.300   0.0      5.800
            BLOCK 4             0.   0.300   1.000   1.300   0.0     0.0        0.   3.650   0.300   0.0      5.800
            BLOCK 5             0.   0.300   1.000   1.300   0.0     0.0        0.   3.650   0.300   0.0      5.800
```

(continue)

TABLE B2 (continued)

```
  UPPER ZONE

    AVERAGE              0.  29.200   0.0    29.200  0.0     0.0        0. 112.000  0.0     0.0    134.200
          BLOCK 1        0.  29.200   0.0    29.200  0.0     0.0        0. 112.000  0.0     0.0    134.200
          BLOCK 2        0.  29.200   0.0    29.200  0.0     0.0        0. 112.000  0.0     0.0    134.200
          BLOCK 3        0.  29.200   0.0    29.200  0.0     0.0        0. 112.000  0.0     0.0    134.200
          BLOCK 4        0.  29.200   0.0    29.200  0.0     0.0        0. 112.000  0.0     0.0    134.200
          BLOCK 5        0.  29.200   0.0    29.200  0.0     0.0        0. 112.000  0.0     0.0    134.200

APPLICATION FOR DAY 176

  SURFACE LAYER

    AVERAGE              0.  14.200   0.200  14.200  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 1        0.  14.200   0.200  14.200  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 2        0.  14.200   0.200  14.200  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 3        0.  14.200   0.200  14.200  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 4        0.  14.200   0.200  14.200  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 5        0.  14.200   0.200  14.200  0.0     0.0        0.   0.0    0.0     0.0      0.0

  UPPER ZONE

    AVERAGE              0.  14.100   0.0    14.300  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 1        0.  14.100   0.0    14.300  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 2        0.  14.100   0.0    14.300  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 3        0.  14.100   0.0    14.300  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 4        0.  14.100   0.0    14.300  0.0     0.0        0.   0.0    0.0     0.0      0.0
          BLOCK 5        0.  14.100   0.0    14.300  0.0     0.0        0.   0.0    0.0     0.0      0.0

LOWER ZONE MONTHLY SOIL TEMPERATURES =    38.2  36.6  37.1  40.1  48.5  56.5  62.4  65.1  64.5  58.7  51.3  44.3

SOIL TEMPERATURE REGRESSION EQUATION CONSTANTS
SURFACE ZONE:  ASZT =   24.270    BSZT=    0.630
UPPER ZONE:    AUZT =    0.0      BUZT=    1.000

SOIL ZONES DEPTHS AND BULK DENSITIES
SZDPTH=   0.1250       UZDPTH=   3.1250       BDSZ=  63.7000       BDUZ=  72.4000       BDLZ=  99.0000
LEACHING FACTORS
UZF =  5.000       LZF =  1.000
```

TABLE B3. MONTHLY SUMMARY - HYDROLOGY (WITHOUT SNOW), SEDIMENT, AND PESTICIDE SIMULATION

SUMMARY FOR MONTH OF MAY 1973

	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	TOTAL
WATER, INCHES						
RUNOFF						
OVERLAND FLOW	2.901	2.698	2.537	2.391	2.253	2.556
INTERFLOW	0.063	0.141	0.199	0.251	0.297	0.190
IMPERVIOUS						0.0
TOTAL	2.963	2.838	2.736	2.642	2.550	2.746
BASE FLOW						0.0
GRDWATER RECHARGE						0.309
PRECIPITATION	5.50	5.50	5.50	5.50	5.50	5.50
EVAPOTRANSPIRATION						
POTENTIAL	2.93	2.93	2.93	2.93	2.93	2.93
NET	2.72	2.72	2.72	2.72	2.72	2.72
CROP COVER						0.13
STORAGES						
UPPER ZONE	1.377	1.368	1.362	1.357	1.353	1.363
LOWER ZONE	23.139	23.139	23.139	23.139	23.139	23.139
GROUNDWATER	0.0	0.0	0.0	0.0	0.0	0.0
INTERCEPTION	0.018	0.018	0.018	0.018	0.018	0.018
OVERLAND FLOW	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW	0.0	0.0	0.0	0.0	0.0	0.0
WATER BALANCE= 0.0						
SEDIMENT, TONS/ACRE						
ERODED SEDIMENT	2.378	2.377	2.375	2.369	2.344	2.368
FINES DEPOSIT	0.002	0.004	0.005	0.012	0.037	0.012
PESTICIDE, POUNDS						
SURFACE LAYER	1.167	1.167	1.167	1.167	1.169	5.836
ADSORBED	1.167	1.167	1.167	1.167	1.169	5.836
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
UPPER ZONE LAYER	0.0	0.0	0.0	0.0	0.0	0.0
ADSORBED	0.0	0.0	0.0	0.0	0.0	0.0
CRYSTALLINE	0.0	0.0	0.0	0.0	0.0	0.0
DISSOLVED	0.0	0.0	0.0	0.0	0.0	0.0
INTERFLOW STORAGE	0.0	0.0	0.0	0.0	0.0	0.0
LOWER ZONE LAYER						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
GROUNDWATER LAYER						0.0
ADSORBED						0.0
CRYSTALLINE						0.0
DISSOLVED						0.0
PESTICIDE REMOVAL, LBS.	0.130	0.130	0.130	0.129	0.128	0.647
OVERLAND FLOW REMOVAL	0.0	0.0	0.0	0.0	0.0	0.0
SEDIMENT REMOVAL	0.130	0.130	0.130	0.129	0.128	0.647
INTERFLOW REMOVAL	0.0	0.0	0.0	0.0	0.0	0.0

(continue)

TABLE B3 (continued)

```
PESTICIDE DEGRADATION LOSS, LBS.
   TOTAL                                                                  0.237
   FROM SURFACE                                                           0.237
   FROM UPPER ZONE                                                        0.0
   FROM LOWER ZONE                                                        0.0

   PESTICIDE BALANCE=  0.0
```

TABLE B4. MONTHLY SUMMARY - HYDROLOGY (WITH SNOW), SEDIMENT, AND NUTRIENT SIMULATION

```
                     SUMMARY FOR MONTH OF  JANUARY 1974

                          BLOCK 1   BLOCK 2   BLOCK 3   BLOCK 4   BLOCK 5    TOTAL

      WATER, INCHES

        RUNOFF
          OVERLAND FLOW    0.698     0.403     0.212     0.080     0.024     0.283
          INTERFLOW        0.086     0.216     0.270     0.279     0.252     0.221
          IMPERVIOUS                                                       0.0
          TOTAL            0.784     0.618     0.481     0.360     0.276     0.504

        BASE FLOW                                                          0.0
        GRDWATER RECHARGE                                                  0.365

        PRECIPITATION      1.70      1.70      1.70      1.70      1.70      1.70
          SNOW                                                             1.13
          RAIN ON SNOW                                                     0.57
          MELT & RAIN                                                      1.10

        MELT
          RADIATION                                                       -0.11
          CONVECTION                                                       0.49
          CONDENSATION                                                     0.12
          RAIN MELT                                                        0.02
          GROUND MELT                                                      0.0
          CUM NEG HEAT                                                     0.00

        SNOW PACK                                                          0.56
        SNOW DENSITY                                                       0.22
        % SNOW COVER                                                      55.68

        SNOW EVAP                                                          0.03

        EVAPOTRANSPIRATION
          POTENTIAL        0.03      0.03      0.03      0.03      0.03      0.03
          NET              0.00      0.00      0.00      0.00      0.00      0.00
          CROP COVER                                                       0.0

        STORAGES
          UPPER ZONE       0.559     0.540     0.520     0.505     0.486     0.522
          LOWER ZONE      11.183    11.183    11.183    11.183    11.183    11.183
          GROUNDWATER      0.0       0.0       0.0       0.0       0.0       0.0
          INTERCEPTION     0.0       0.0       0.0       0.0       0.0       0.0
          OVERLAND FLOW    0.0       0.0       0.0       0.0       0.0       0.0
          INTERFLOW        0.0       0.0       0.0       0.0       0.0       0.0

        WATER BALANCE=  0.0
        SNOW BALANCE=   0.0
```

(continue)

TABLE B4 (continued)

```
   SEDIMENT, TONS/ACRE
     ERODED SEDIMENT         0.178      0.097      0.047      0.016      0.005       0.069
     FINES DEPOSIT           0.822      0.903      0.953      0.985      0.996       0.932

 NUTRIENTS - LB/AC          ORG-N   NH4-S   NH4-A   NO3+NO2    N2  PLNT-N   ORG-P   PO4-S   PO4-A  PLNT-P      CL

   STORAGE

     SURFACE LAYER          68.81   0.013   0.665   0.0      0.0     0.0    40.16   0.004   2.577   0.0      0.0
       BLOCK 1              68.29   0.013   0.661   0.0      0.0     0.0    39.85   0.004   2.558   0.0      0.0
       BLOCK 2              68.67   0.013   0.664   0.0      0.0     0.0    40.08   0.004   2.572   0.0      0.0
       BLOCK 3              68.91   0.013   0.666   0.0      0.0     0.0    40.21   0.004   2.581   0.0      0.0
       BLOCK 4              69.06   0.013   0.667   0.0      0.0     0.0    40.30   0.004   2.587   0.0      0.0
       BLOCK 5              69.11   0.013   0.668   0.0      0.0     0.0    40.33   0.004   2.589   0.0      0.0

     UPPER ZONE            439.77   1.611   9.431   8.970    0.240   0.0   219.89   1.205 111.708   0.0     51.800
       BLOCK 1             439.77   2.087   9.610  14.866    0.305   0.0   219.89   1.797 111.826   0.0     66.580
       BLOCK 2             439.77   1.664   9.477   9.793    0.236   0.0   219.89   1.283 111.738   0.0     56.708
       BLOCK 3             439.77   1.488   9.398   7.592    0.228   0.0   219.89   1.062 111.686   0.0     43.707
       BLOCK 4             439.77   1.417   9.346   6.490    0.209   0.0   219.89   0.958 111.652   0.0     37.160
       BLOCK 5             439.77   1.398   9.322   6.104    0.201   0.0   219.89   0.924 111.636   0.0     34.844

     INTERFLOW               0.0    0.000   0.0     0.002    0.0     0.0     0.0    0.000   0.0     0.0      0.009
       BLOCK 1               0.0    0.001   0.0     0.008    0.0     0.0     0.0    0.001   0.0     0.0      0.044
       BLOCK 2               0.0    0.0     0.0     0.0      0.0     0.0     0.0    0.0     0.0     0.0      0.0
       BLOCK 3               0.0    0.0     0.0     0.0      0.0     0.0     0.0    0.0     0.0     0.0      0.0
       BLOCK 4               0.0    0.0     0.0     0.0      0.0     0.0     0.0    0.0     0.0     0.0      0.0
       BLOCK 5               0.0    0.0     0.0     0.0      0.0     0.0     0.0    0.0     0.0     0.0      0.0

     LOWER ZONE           1488.00  20.362  30.000 153.701    0.0     0.0   800.00  20.197 200.000   0.0     42.044

     GROUNDWATER             0.0    0.709   0.0     5.331    0.0     0.0     0.0    0.701   0.0     0.0      0.875

   REMOVAL

     ADVECTIVE

       SEDIMENT              0.33   0.0     0.004   0.0      0.0     0.0     0.19   0.0     0.012   0.0      0.0
         BLOCK 1             0.85   0.0     0.010   0.0      0.0     0.0     0.50   0.0     0.032   0.0      0.0
         BLOCK 2             0.46   0.0     0.006   0.0      0.0     0.0     0.27   0.0     0.017   0.0      0.0
         BLOCK 3             0.22   0.0     0.003   0.0      0.0     0.0     0.13   0.0     0.008   0.0      0.0
         BLOCK 4             0.08   0.0     0.001   0.0      0.0     0.0     0.04   0.0     0.003   0.0      0.0
         BLOCK 5             0.02   0.0     0.000   0.0      0.0     0.0     0.01   0.0     0.001   0.0      0.0
```

(continue)

TABLE B4 (continued)

OVERLAND FLOW	0.0	0.079	0.0	0.000	0.0	0.0	0.0	0.025	0.0	0.0	0.0
BLOCK 1	0.0	0.223	0.0	0.000	0.0	0.0	0.0	0.072	0.0	0.0	0.0
BLOCK 2	0.0	0.103	0.0	0.000	0.0	0.0	0.0	0.033	0.0	0.0	0.0
BLOCK 3	0.0	0.046	0.0	0.000	0.0	0.0	0.0	0.014	0.0	0.0	0.0
BLOCK 4	0.0	0.016	0.0	0.000	0.0	0.0	0.0	0.005	0.0	0.0	0.0
BLOCK 5	0.0	0.004	0.0	0.000	0.0	0.0	0.0	0.001	0.0	0.0	0.0
INTERFLOW	0.0	1.016	0.0	5.758	0.0	0.0	0.0	0.738	0.0	0.0	35.272
BLOCK 1	0.0	0.508	0.0	3.121	0.0	0.0	0.0	0.389	0.0	0.0	18.942
BLOCK 2	0.0	0.998	0.0	5.802	0.0	0.0	0.0	0.739	0.0	0.0	35.328
BLOCK 3	0.0	1.181	0.0	6.639	0.0	0.0	0.0	0.855	0.0	0.0	40.610
BLOCK 4	0.0	1.227	0.0	6.799	0.0	0.0	0.0	0.877	0.0	0.0	41.809
BLOCK 5	0.0	1.167	0.0	6.429	0.0	0.0	0.0	0.830	0.0	0.0	39.671
TOTAL TO STREAM	0.33	1.095	0.004	5.758	0.0	0.0	0.19	0.763	0.012	0.0	35.272
PERCOLATION TO GROUNDWATER	0.0	0.709	0.0	5.331	0.0	0.0	0.0	0.701	0.0	0.0	0.875
BIOLOGICAL - TOTAL	0.0	0.0	0.0	0.0	0.240	0.0	0.0	0.0	0.0	0.0	0.0
SURFACE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UPPER ZONE	0.0	0.0	0.0	0.0	0.240	0.0	0.0	0.0	0.0	0.0	0.0
LOWER ZONE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GROUNDWATER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HARVEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MASS BALANCE
NITROGEN = -0.000
PHOSPHORUS = -0.001
CHLORIDE = -0.001

TABLE B5. DAILY PRODUCTION RUN SUMMARY (HYCAL=PROD) - HYDROLOGY (WITHOUT SNOW), SEDIMENT, AND PESTICIDE SIMULATION

```
                              24: 0  ON  28  MAY    1973

                              BLOCK 1   BLOCK 2   BLOCK 3   BLOCK 4   BLOCK 5     TOTAL

  WATER, INCHES

     RUNOFF
        OVERLAND FLOW          2.889     2.690     2.532     2.388     2.251     2.550
        INTERFLOW              0.058     0.131     0.187     0.237     0.282     0.179
        IMPERVIOUS                                                               0.0
        TOTAL                  2.947     2.821     2.719     2.625     2.533     2.729

     BASE FLOW                                                                   0.0
     GRDWATER RECHARGE                                                           0.403

     PRECIPITATION             4.27      4.27      4.27      4.27      4.27      4.27

     EVAPOTRANSPIRATION
        POTENTIAL              0.15      0.15      0.15      0.15      0.15      0.15
        NET                    0.15      0.15      0.15      0.15      0.15      0.15
        CROP COVER                                                               0.13

     STORAGES
        UPPER ZONE             1.377     1.368     1.362     1.357     1.353     1.363
        LOWER ZONE            23.139    23.139    23.139    23.139    23.139    23.139
        GROUNDWATER            0.0       0.0       0.0       0.0       0.0       0.0
        INTERCEPTION           0.018     0.018     0.018     0.018     0.018     0.018
        OVERLAND FLOW          0.0       0.0       0.0       0.0       0.0       0.0
        INTERFLOW              0.0       0.0       0.0       0.0       0.0       0.0

     WATER BALANCE=  0.0

  SEDIMENT, TONS/ACRE
     ERODED SEDIMENT           2.377     2.376     2.374     2.368     2.343     2.368
     FINES DEPOSIT             0.002     0.004     0.005     0.012     0.037     0.012

SURFACE LAYER PESTICIDE

  PESTICIDE, LBS               1.169     1.169     1.169     1.170     1.171     5.848
     ADSORBED                  1.169     1.169     1.169     1.170     1.171     5.848
     CRYSTALLINE               0.0       0.0       0.0       0.0       0.0       0.0
     DISSOLVED                 0.0       0.0       0.0       0.0       0.0       0.0

  PESTICIDE, PPM              40.299    40.301    40.304    40.316    40.362    40.316
     ADSORBED                 40.299    40.301    40.304    40.316    40.362    40.316
     CRYSTALLINE               0.0       0.0       0.0       0.0       0.0       0.0
     DISSOLVED                 0.0       0.0       0.0       0.0       0.0       0.0

  REMOVAL, LBS                 0.130     0.130     0.130     0.129     0.128     0.647
     SEDIMENT                  0.130     0.130     0.130     0.129     0.128     0.647
     OVERLAND FLOW             0.0       0.0       0.0       0.0       0.0       0.0
     PERCOLATION               0.0       0.0       0.0       0.0       0.0       0.0

UPPER ZONE LAYER PESTICIDE

  PESTICIDE, LBS               0.0       0.0       0.0       0.0       0.0       0.0
     ADSORBED                  0.0       0.0       0.0       0.0       0.0       0.0
     CRYSTALLINE               0.0       0.0       0.0       0.0       0.0       0.0
     DISSOLVED                 0.0       0.0       0.0       0.0       0.0       0.0
     INTERFLOW STORAGE         0.0       0.0       0.0       0.0       0.0       0.0

  PESTICIDE, PPM               0.0       0.0       0.0       0.0       0.0       0.0
     ADSORBED                  0.0       0.0       0.0       0.0       0.0       0.0
     CRYSTALLINE               0.0       0.0       0.0       0.0       0.0       0.0
     DISSOLVED                 0.0       0.0       0.0       0.0       0.0       0.0
```

(continue)

TABLE B5 (continued)

```
   REMOVAL, LBS               0.0       0.0       0.0       0.0       0.0        0.0
      INTERFLOW               0.0       0.0       0.0       0.0       0.0        0.0
      PERCOLATION             0.0       0.0       0.0       0.0       0.0        0.0

LOWER ZONE LAYER PESTICIDE

   PESTICIDE, LBS                                                                0.0
      ADSORBED                                                                   0.0
      CRYSTALLINE                                                                0.0
      DISSOLVED                                                                  0.0

   PESTICIDE, PPM
      ADSORBED                                                                   0.0
      CRYSTALLINE                                                                0.0
      DISSOLVED                                                                  0.0

   REMOVAL, LBS                                                                  0.0
      PERCOLATION                                                                0.0

GROUNDWATER LAYER PESTICIDE

   PESTICIDE, LBS                                                                0.0
      ADSORBED                                                                   0.0
      CRYSTALLINE                                                                0.0
      DISSOLVED                                                                  0.0

PESTICIDE DEGRADATION LOSS, LBS.
   TOTAL                                                                         0.012
   FROM SURFACE                                                                  0.012
   FROM UPPER ZONE                                                               0.0
   FROM LOWER ZONE                                                               0.0
```

TABLE B6. DAILY PRODUCTION RUN SUMMARY (HYCAL=PROD) - HYDROLOGY (WITH SNOW), SEDIMENT, AND NUTRIENT SIMULATION

24: 0 ON 20 JANUARY 1974

	BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4	BLOCK 5	TOTAL
WATER, INCHES						
RUNOFF						
OVERLAND FLOW	0.487	0.332	0.198	0.080	0.024	0.224
INTERFLOW	0.036	0.105	0.166	0.221	0.228	0.151
IMPERVIOUS						0.0
TOTAL	0.523	0.438	0.364	0.300	0.252	0.375
BASE FLOW						0.0
GRDWATER RECHARGE						0.190
PRECIPITATION	1.61	1.61	1.61	1.61	1.61	1.61
SNOW						1.13
RAIN ON SNOW						0.48
MELT & RAIN						0.72
MELT						
RADIATION						-0.03
CONVECTION						0.16
CONDENSATION						0.12
RAIN MELT						0.02
GROUND MELT						0.0
CUM NEG HEAT						0.00
SNOW PACK						0.86
SNOW DENSITY						0.23
% SNOW COVER						86.13
SNOW EVAP						0.00
EVAPOTRANSPIRATION						
POTENTIAL	0.01	0.01	0.01	0.01	0.01	0.01
NET	0.00	0.00	0.00	0.00	0.00	0.00
CROP COVER						0.0
STORAGES						
UPPER ZONE	0.579	0.570	0.559	0.541	0.518	0.553
LOWER ZONE	11.092	11.092	11.092	11.092	11.092	11.092
GROUNDWATER	0.0	0.0	0.0	0.0	0.0	0.0
INTERCEPTION	0.0	0.0	0.0	0.0	0.0	0.0
OVERLAND FLOW	0.014	0.012	0.008	0.004	0.0	0.008
INTERFLOW	0.001	0.003	0.004	0.006	0.005	0.004

(continue)

TABLE B6 (continued)

```
            WATER BALANCE=  0.0
            SNOW BALANCE=   0.0

           SEDIMENT, TONS/ACRE
            ERODED SEDIMENT        0.133     0.084     0.044     0.016     0.003      0.056
            FINES DEPOSIT          0.867     0.917     0.956     0.984     0.996      0.944


   NUTRIENTS - LB/AC           ORG-N   NH4-S   NH4-A   NO3+NO2    N2  PLNT-N   ORG-P   PO4-S   PO4-A  PLNT-P     CL

     SURFACE LAYER

       STORAGE                 69.03   0.014   0.801   0.000   0.0     0.0     40.28   0.004   2.586   0.0     0.0
           BLOCK 1             68.66   0.014   0.797   0.000   0.0     0.0     40.07   0.004   2.572   0.0     0.0
           BLOCK 2             68.90   0.014   0.800   0.000   0.0     0.0     40.21   0.004   2.581   0.0     0.0
           BLOCK 3             69.08   0.014   0.802   0.000   0.0     0.0     40.32   0.004   2.588   0.0     0.0
           BLOCK 4             69.22   0.014   0.803   0.000   0.0     0.0     40.40   0.004   2.593   0.0     0.0
           BLOCK 5             69.27   0.014   0.804   0.0     0.0     0.0     40.43   0.004   2.595   0.0     0.0

       REMOVAL

         SEDIMENT               0.27   0.0     0.003   0.0     0.0     0.0      0.16   0.0     0.010   0.0     0.0
           BLOCK 1              0.64   0.0     0.008   0.0     0.0     0.0      0.37   0.0     0.024   0.0     0.0
           BLOCK 2              0.40   0.0     0.005   0.0     0.0     0.0      0.23   0.0     0.015   0.0     0.0
           BLOCK 3              0.21   0.0     0.003   0.0     0.0     0.0      0.12   0.0     0.008   0.0     0.0
           BLOCK 4              0.08   0.0     0.001   0.0     0.0     0.0      0.04   0.0     0.003   0.0     0.0
           BLOCK 5              0.02   0.0     0.000   0.0     0.0     0.0      0.01   0.0     0.001   0.0     0.0

         OVERLAND FLOW          0.0    0.049   0.0     0.000   0.0     0.0      0.0    0.015   0.0     0.0     0.0
           BLOCK 1              0.0    0.111   0.0     0.000   0.0     0.0      0.0    0.035   0.0     0.0     0.0
           BLOCK 2              0.0    0.073   0.0     0.000   0.0     0.0      0.0    0.023   0.0     0.0     0.0
           BLOCK 3              0.0    0.042   0.0     0.000   0.0     0.0      0.0    0.013   0.0     0.0     0.0
           BLOCK 4              0.0    0.015   0.0     0.000   0.0     0.0      0.0    0.005   0.0     0.0     0.0
           BLOCK 5              0.0    0.004   0.0     0.000   0.0     0.0      0.0    0.001   0.0     0.0     0.0

         PERCOLATION            0.0    0.347   0.0     0.300   0.0     0.0      0.0    1.345   0.0     0.0     0.0
           BLOCK 1              0.0    0.284   0.0     0.300   0.0     0.0      0.0    1.326   0.0     0.0     0.0
           BLOCK 2              0.0    0.323   0.0     0.300   0.0     0.0      0.0    1.338   0.0     0.0     0.0
           BLOCK 3              0.0    0.354   0.0     0.300   0.0     0.0      0.0    1.348   0.0     0.0     0.0
           BLOCK 4              0.0    0.381   0.0     0.300   0.0     0.0      0.0    1.356   0.0     0.0     0.0
           BLOCK 5              0.0    0.392   0.0     0.300   0.0     0.0      0.0    1.360   0.0     0.0     0.0

         BIOLOGICAL             0.0    0.0     0.0     0.0     0.0     0.0      0.0    0.0     0.0     0.0     0.0
           BLOCK 1              0.0    0.0     0.0     0.0     0.0     0.0      0.0    0.0     0.0     0.0     0.0
           BLOCK 2              0.0    0.0     0.0     0.0     0.0     0.0      0.0    0.0     0.0     0.0     0.0
           BLOCK 3              0.0    0.0     0.0     0.0     0.0     0.0      0.0    0.0     0.0     0.0     0.0
           BLOCK 4              0.0    0.0     0.0     0.0     0.0     0.0      0.0    0.0     0.0     0.0     0.0
           BLOCK 5              0.0    0.0     0.0     0.0     0.0     0.0      0.0    0.0     0.0     0.0     0.0
```

(continue)

TABLE B6 (continued)

UPPER ZONE											
STORAGE	439.89	2.126	9.883	12.457	0.146	0.0	219.95	1.583	111.706	0.0	73.854
BLOCK 1	439.89	2.914	9.932	17.919	0.158	0.0	219.95	2.234	111.732	0.0	109.165
BLOCK 2	439.89	2.397	9.900	14.294	0.150	0.0	219.95	1.803	111.715	0.0	87.055
BLOCK 3	439.89	2.022	9.878	11.712	0.144	0.0	219.95	1.495	111.703	0.0	71.306
BLOCK 4	439.89	1.716	9.860	9.643	0.140	0.0	219.95	1.246	111.694	0.0	58.694
BLOCK 5	439.89	1.583	9.847	8.717	0.136	0.0	219.95	1.136	111.687	0.0	53.052
INTERFLOW	0.0	0.013	0.0	0.075	0.0	0.0	0.0	0.010	0.0	0.0	0.459
BLOCK 1	0.0	0.004	0.0	0.026	0.0	0.0	0.0	0.003	0.0	0.0	0.160
BLOCK 2	0.0	0.011	0.0	0.064	0.0	0.0	0.0	0.008	0.0	0.0	0.389
BLOCK 3	0.0	0.015	0.0	0.089	0.0	0.0	0.0	0.011	0.0	0.0	0.540
BLOCK 4	0.0	0.019	0.0	0.104	0.0	0.0	0.0	0.013	0.0	0.0	0.636
BLOCK 5	0.0	0.017	0.0	0.094	0.0	0.0	0.0	0.012	0.0	0.0	0.571
REMOVAL											
INTERFLOW	0.0	0.775	0.0	4.312	0.0	0.0	0.0	0.554	0.0	0.0	26.627
BLOCK 1	0.0	0.265	0.0	1.490	0.0	0.0	0.0	0.190	0.0	0.0	9.220
BLOCK 2	0.0	0.609	0.0	3.421	0.0	0.0	0.0	0.437	0.0	0.0	21.135
BLOCK 3	0.0	0.853	0.0	4.770	0.0	0.0	0.0	0.611	0.0	0.0	29.445
BLOCK 4	0.0	1.053	0.0	5.850	0.0	0.0	0.0	0.752	0.0	0.0	36.096
BLOCK 5	0.0	1.094	0.0	6.028	0.0	0.0	0.0	0.777	0.0	0.0	37.240
PERCOLATION	0.0	0.796	0.0	4.362	0.0	0.0	0.0	0.547	0.0	0.0	27.058
BLOCK 1	0.0	0.333	0.0	1.841	0.0	0.0	0.0	0.221	0.0	0.0	11.455
BLOCK 2	0.0	0.625	0.0	3.450	0.0	0.0	0.0	0.428	0.0	0.0	21.420
BLOCK 3	0.0	0.842	0.0	4.628	0.0	0.0	0.0	0.580	0.0	0.0	28.707
BLOCK 4	0.0	1.019	0.0	5.576	0.0	0.0	0.0	0.704	0.0	0.0	34.573
BLOCK 5	0.0	1.159	0.0	6.315	0.0	0.0	0.0	0.801	0.0	0.0	39.137
BIOLOGICAL	0.0	0.0	0.0	0.0	0.146	0.0	0.0	0.0	0.0	0.0	0.0
BLOCK 1	0.0	0.0	0.0	0.0	0.158	0.0	0.0	0.0	0.0	0.0	0.0
BLOCK 2	0.0	0.0	0.0	0.0	0.150	0.0	0.0	0.0	0.0	0.0	0.0
BLOCK 3	0.0	0.0	0.0	0.0	0.144	0.0	0.0	0.0	0.0	0.0	0.0
BLOCK 4	0.0	0.0	0.0	0.0	0.140	0.0	0.0	0.0	0.0	0.0	0.0
BLOCK 5	0.0	0.0	0.0	0.0	0.136	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL TO STREAM	0.27	0.823	0.003	4.312	0.0	0.0	0.16	0.569	0.010	0.0	26.627
LOWER ZONE											
STORAGE	1488.00	20.447	50.000	153.729	0.0	0.0	800.00	20.201	200.000	0.0	26.798

(continue)

TABLE B6 (continued)

```
      REMOVAL

         PERCOLATION        0.0   0.349  0.0   2.633  0.0   0.0    0.0  0.346  0.0   0.0   0.261

         BIOLOGICAL         0.0   0.0    0.0   0.0    0.0   0.0    0.0  0.0    0.0   0.0   0.0

     GROUNDWATER

      STORAGE               0.0   0.349  0.0   2.633  0.0   0.0    0.0  0.346  0.0   0.0   0.261

      REMOVAL

         BIOLOGICAL         0.0   0.0    0.0   0.0    0.0   0.0    0.0  0.0    0.0   0.0   0.0

   DAILY SOIL TEMPERATURE IN DEGREE F

     SURFACE ZONE MAX(4PM)  MIN(6AM)
                 49.3      43.2

     UPPER ZONE   MAX(4PM)  MIN(6AM)
                 49.3       6.2

     LOWER ZONE DAILY AVERAGE
               37.3
```

TABLE B7. STORM EVENT CALIBRATION RUN OUTPUT (HYCAL=CALB) - HYDROLOGY AND SEDIMENT SIMULATION

```
     DATE        TIME     FLOW(CFS-CMS)          SEDIMENT  (LBS-KG-KG/MIN-GM/L)


SEPTMBER   9   20:45     0.006     0.000        0.13        0.06       0.01       1.11
SEPTMBER   9   20:50     0.188     0.005       10.53        4.78       0.96       3.00   *
SEPTMBER   9   20:55     0.721     0.020       31.96       14.51       2.90       2.37   *
SEPTMBER   9   21: 0     1.724     0.049       77.37       35.13       7.03       2.40   **
SEPTMBER   9   21: 5     1.450     0.041       44.48       20.19       4.04       1.64   *
SEPTMBER   9   21:10     0.678     0.019       10.21        4.64       0.93       0.80   *
SEPTMBER   9   21:15     0.545     0.015        6.55        2.97       0.59       0.64   *
SEPTMBER   9   21:20     0.427     0.012        4.61        2.09       0.42       0.58   *
SEPTMBER   9   21:25     0.514     0.015        6.26        2.84       0.57       0.65   *
SEPTMBER   9   21:30     2.649     0.075      146.43       66.48      13.30       2.95   ***
SEPTMBER   9   21:35     4.624     0.131      276.02      125.31      25.06       3.19   ***
SEPTMBER   9   21:40     2.954     0.084      130.76       59.36      11.87       2.37   ***
SEPTMBER   9   21:45     1.693     0.048       37.12       16.85       3.37       1.17   **
SEPTMBER   9   21:50     0.837     0.024       10.43        4.73       0.95       0.67   *
SEPTMBER   9   21:55     0.510     0.014        2.31        1.05       0.21       0.24   *
SEPTMBER   9   22: 0     0.334     0.009        1.16        0.53       0.11       0.19   *
SEPTMBER   9   22: 5     0.214     0.006        0.82        0.37       0.07       0.21   *
SEPTMBER   9   22:10     0.138     0.004        0.25        0.11       0.02       0.10
SEPTMBER   9   22:15     0.092     0.003        0.01        0.00       0.00       0.00
SEPTMBER   9   22:20     0.067     0.002        0.0         0.0        0.0        0.0
SEPTMBER   9   22:25     0.044     0.001        0.0         0.0        0.0        0.0
SEPTMBER   9   22:30     0.030     0.001        0.0         0.0        0.0        0.0
SEPTMBER   9   22:35     0.020     0.001        0.0         0.0        0.0        0.0
SEPTMBER   9   22:40     0.013     0.000        0.0         0.0        0.0        0.0
SEPTMBER   9   22:45     0.009     0.000        0.0         0.0        0.0        0.0
SEPTMBER   9   22:50     0.006     0.000        0.0         0.0        0.0        0.0
SEPTMBER   9   22:55     0.004     0.000        0.0         0.0        0.0        0.0
```

Note: Asterisks (*) indicate that the detached fines storage is less than the overland flow sediment transport capacity in an areal zone (or block), e.g. three asterisks (***) indicate that this occurs in three such zones.

TABLE B8. STORM EVENT CALIBRATION RUN OUTPUT (HYCAL=CALB) - HYDROLOGY, SEDIMENT, AND PESTICIDE SIMULATION

```
                                                                                    PESTICIDE (GM-GM/MIN-PPM)
 DATE     TIME    FLOW(CFS-CMS)      SEDIMENT (LBS-KG-KG/MIN-GM/L)             WATER                          SEDIMENT



PESTICIDE APPLICATION OCCURS ON   MAY    11  (TIMAP=131) WITH AN APPLICATION OF 2.100 LBS/AC

BEGINNING ON   MAY    11  (DDG=131) THE PESTICIDE DEGRADATION RATE (KDG) EQUALS    0.002
  MAY    24   0:55    0.056   0.002      0.72     0.33     0.07     0.68     0.0      0.0      0.0       0.015     0.003   45.136
  MAY    24  10:20    0.080   0.002      1.89     0.86     0.17     1.26     0.0      0.0      0.0       0.039     0.008   45.136
  MAY    24  10:25    0.064   0.002      0.53     0.24     0.05     0.44     0.0      0.0      0.0       0.011     0.002   45.134
  MAY    28   3:55    0.171   0.005      8.51     3.86     0.77     2.66     0.0      0.0      0.0       0.173     0.035   44.774
  MAY    28   4: 0    0.448   0.013     32.94    14.96     2.99     3.93     0.0      0.0      0.0       0.670     0.134   44.772
  MAY    28   4: 5    0.793   0.022     68.63    31.16     6.23     4.63     0.0      0.0      0.0       1.395     0.279   44.760
  MAY    28   4:10    0.813   0.023     63.63    28.89     5.78     4.18     0.0      0.0      0.0       1.292     0.258   44.736
  MAY    28   4:15    1.059   0.030    105.94    48.10     9.62     5.34     0.0      0.0      0.0       2.151     0.430   44.715
  MAY    28   4:20    2.209   0.063    314.89   142.96    28.59     7.62     0.0      0.0      0.0       6.388     1.278   44.683
  MAY    28   4:25    5.706   0.161   1310.21   594.83   118.97    12.27     0.0      0.0      0.0      26.521     5.304   44.586
  MAY    28   4:30    7.617   0.216   1779.38   807.84   161.57    12.48     0.0      0.0      0.0      35.692     7.138   44.182
  MAY    28   4:35    5.009   0.142    947.73   430.27    86.05    10.11     0.0      0.0      0.0      18.777     3.755   43.639
  MAY    28   4:40    3.743   0.106    612.35   278.01    55.60     8.74     0.0      0.0      0.0      12.052     2.410   43.350
  MAY    28   4:45    2.726   0.077    367.56   166.87    33.37     7.21     0.0      0.0      0.0       7.203     1.441   43.163
  MAY    28   4:50    2.080   0.059    249.83   113.42    22.68     6.42     0.0      0.0      0.0       4.883     0.977   43.048
  MAY    28   4:55    3.054   0.086    499.56   226.80    45.36     8.74     0.0      0.0      0.0       9.747     1.949   42.977
  MAY    28   5: 0    5.638   0.160   1207.17   548.05   109.61    11.44     0.0      0.0      0.0      23.475     4.695   42.834
  MAY    28   5: 5    3.521   0.100    474.06   215.22    43.04     7.20     0.0      0.0      0.0       9.141     1.828   42.474
  MAY    28   5:10    1.020   0.029     70.00    31.78     6.36     3.67     0.0      0.0      0.0       1.344     0.269   42.308
  MAY    28   5:15    0.501   0.014     20.10     9.12     1.82     2.14     0.0      0.0      0.0       0.385     0.077   42.236
  MAY    28   5:20    0.295   0.008      6.61     3.00     0.60     1.20     0.0      0.0      0.0       0.127     0.025   42.150
  MAY    28   5:25    0.205   0.006      2.44     1.11     0.22     0.64     0.0      0.0      0.0       0.047     0.009   42.071
  MAY    28   5:30    0.152   0.004      1.03     0.47     0.09     0.36     0.0      0.0      0.0       0.020     0.004   42.026
  MAY    28   5:35    0.112   0.003      0.48     0.22     0.04     0.23     0.0      0.0      0.0       0.009     0.002   42.000
  MAY    28   5:40    0.079   0.002      0.23     0.11     0.02     0.16     0.0      0.0      0.0       0.004     0.001   41.981
  MAY    28   5:45    0.060   0.002      0.12     0.06     0.01     0.11     0.0      0.0      0.0       0.002     0.000   41.981
  MAY    28  17:45    1.333   0.038    211.11    95.85    19.17     8.46     0.0      0.0      0.0       4.055     0.811   42.308
  MAY    28  17:50    8.956   0.253   2327.65  1056.75   211.35    13.89     0.0      0.0      0.0      44.672     8.934   42.272
  MAY    28  17:55    5.224   0.148    849.71   385.77    77.15     8.69     0.0      0.0      0.0      16.037     3.207   41.573
  MAY    28  18: 0    0.969   0.027     68.47    31.09     6.22     3.78     0.0      0.0      0.0       1.284     0.257   41.304
  MAY    28  18: 5    0.442   0.013     17.69     8.03     1.61     2.14     0.0      0.0      0.0       0.331     0.066   41.236
  MAY    28  18:10    0.250   0.007      5.23     2.38     0.48     1.12     0.0      0.0      0.0       0.098     0.020   41.153
  MAY    28  18:15    0.171   0.005      1.75     0.79     0.16     0.55     0.0      0.0      0.0       0.033     0.007   41.086
  MAY    28  18:20    0.128   0.004      0.68     0.31     0.06     0.28     0.0      0.0      0.0       0.013     0.003   41.056
  MAY    28  18:25    0.095   0.003      0.29     0.13     0.03     0.16     0.0      0.0      0.0       0.005     0.001   41.040
  MAY    28  18:30    0.068   0.002      0.13     0.06     0.01     0.10     0.0      0.0      0.0       0.002     0.000   41.032
  MAY    28  18:45    3.974   0.112    729.48   331.19    66.24     9.81     0.0      0.0      0.0      13.697     2.739   41.358
  MAY    28  18:50    7.231   0.205   1230.55   558.67   111.73     9.09     0.0      0.0      0.0      22.970     4.594   41.115
```

TABLE B9. STORM EVENT CALIBRATION RUN OUTPUT (HYCAL=CALB) - HYDROLOGY, SEDIMENT, AND NUTRIENT SIMULATION

					DISSOLVED IN WATER				ADSORBED TO SEDIMENT					
DATE		TIME	FLOW (CFS)	SEDIMENT (LB) (GM/L)	NO3+NO2 (LB) (MG/L)	NH4 (LB) (MG/L)	PO4 (LB) (MG/L)	CL (LB) (MG/L)	NH4 (LB) (PPM)	ORG-N (LB) (PPM)	PO4 (LB) (PPM)	ORG-P (LB) (PPM)	TOT-N (LB) (MG/L)	TOT-P (LB) (MG/L)
JUNE	5	2:40	0.011	0.24 1.21	0.010 49.9	0.001 6.5	0.001 3.8	0.071 357.1	0.000 30.1	0.001 2399.4	0.000 89.9	0.000 1400.2	0.012 59.3	0.001 5.6
JUNE	5	2:45	0.019	0.48 1.32	0.017 47.6	0.002 6.2	0.001 3.6	0.123 340.8	0.000 30.1	0.001 2399.4	0.000 89.9	0.001 1400.2	0.021 57.0	0.002 5.6
JUNE	5	2:50	0.179	11.16 3.32	0.022 6.5	0.003 0.9	0.002 0.5	0.157 46.8	0.000 30.1	0.027 2399.4	0.001 89.9	0.016 1400.2	0.052 15.5	0.018 5.5
JUNE	5	2:55	0.282	15.17 2.88	0.025 4.8	0.003 0.6	0.002 0.4	0.181 34.3	0.000 30.1	0.036 2398.7	0.001 89.9	0.021 1399.8	0.065 12.4	0.025 4.7
JUNE	5	3: 0	0.188	10.05 2.86	0.041 11.6	0.005 1.5	0.003 0.9	0.293 83.2	0.000 30.1	0.024 2398.0	0.001 89.8	0.014 1399.4	0.071 20.1	0.018 5.1
JUNE	5	3: 5	0.240	12.66 2.82	0.052 11.7	0.017 3.7	0.007 1.6	0.376 83.7	0.000 29.7	0.030 2397.0	0.001 89.8	0.018 1398.8	0.100 22.3	0.026 5.8
JUNE	5	3:10	0.473	33.58 3.79	0.061 6.9	0.013 1.5	0.006 0.7	0.435 49.1	0.001 29.7	0.080 2396.6	0.003 89.8	0.047 1398.6	0.155 17.6	0.056 6.4
JUNE	5	3:15	0.565	36.77 3.48	0.066 6.3	0.013 1.2	0.006 0.6	0.477 45.1	0.001 29.6	0.088 2395.1	0.003 89.7	0.051 1397.7	0.169 16.0	0.061 5.8
JUNE	5	3:20	0.202	8.41 2.23	0.072 19.0	0.011 2.9	0.006 1.6	0.514 136.2	0.000 29.6	0.020 2393.3	0.001 89.7	0.012 1396.7	0.103 27.2	0.018 4.9
JUNE	5	3:25	0.073	1.60 1.17	0.076 55.6	0.010 7.5	0.006 4.3	0.543 398.6	0.000 29.6	0.004 2392.1	0.000 89.6	0.002 1395.9	0.090 65.9	0.008 6.0
JUNE	5	3:30	0.042	0.42 0.53	0.079 100.0	0.010 13.2	0.006 7.6	0.568 717.6	0.000 29.6	0.001 2391.1	0.000 89.6	0.001 1395.4	0.091 114.5	0.007 8.4

TABLE B10. DAILY SNOWMELT OUTPUT (SNOWPRINT=YES)
CALIBRATION RUN, ENGLISH UNITS

```
                            SNOWMELT OUTPUT FOR    DECEMBER   1

HOUR     PACK      DEPTH   SDEN  ALBEDO  CLDF    NEGMELT    LIQW      TX     RA   LW     PX      MELT      CONV     RAINM     CONDS     ICE
  1       0.6        3.0  0.204  0.735  1.000    0.013     0.018    23.77   0.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
  2       0.6        3.0  0.204  0.734  1.000    0.017     0.018    22.61   0.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
  3       0.6        3.0  0.204  0.733  1.000    0.021     0.018    21.74   0.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
  4       0.6        3.0  0.205  0.732  1.000    0.023     0.018    21.16   0.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
  5       0.6        3.0  0.205  0.731  1.000    0.024     0.018    20.58   0.  -9.    0.0      0.0      0.0       0.0       0.0      0.4
  6       0.6        3.0  0.205  0.730  1.000    0.025     0.018    20.00   0.  -9.    0.0      0.0      0.0       0.0       0.0      0.4
  7       0.6        3.0  0.204  0.730  1.000    0.024     0.018    20.38   1.  -9.    0.0      0.0      0.0       0.0       0.0      0.4
  8       0.6        3.0  0.204  0.729  1.000    0.022     0.018    21.52   2.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
  9       0.6        3.0  0.204  0.728  1.000    0.016     0.018    24.18   3.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
 10       0.6        3.0  0.204  0.727  1.000    0.009     0.018    27.60   4.  -7.    0.0      0.0      0.0       0.0       0.0      0.4
 11       0.6        3.0  0.203  0.726  1.000    0.001     0.018    31.40   5.  -7.    0.0      0.0      0.0       0.0       0.0      0.4
 12       0.6        3.0  0.202  0.725  1.000    0.001     0.018    34.63   5.  -6.    0.0      0.0      0.002     0.0       0.0      0.4
 13       0.6        2.9  0.203  0.725  1.000    0.0       0.018    37.10   5.  -6.    0.0      0.003    0.005     0.0       0.0      0.4
 14       0.6        2.9  0.204  0.724  1.000    0.0       0.018    38.24   5.  -5.    0.0      0.006    0.006     0.0       0.0      0.4
 15       0.6        2.9  0.205  0.723  1.000    0.0       0.017    38.81   5.  -5.    0.0      0.007    0.007     0.0       0.0      0.4
 16       0.6        2.9  0.206  0.722  1.000    0.0       0.017    39.00   5.  -5.    0.0      0.005    0.007     0.0       0.0      0.4
 17       0.6        2.8  0.205  0.721  1.000    0.0       0.017    38.05   4.  -5.    0.0      0.002    0.006     0.0       0.0      0.4
 18       0.6        2.8  0.204  0.721  1.000    0.0       0.017    36.72   3.  -6.    0.0      0.0      0.004     0.0       0.0      0.4
 19       0.6        2.8  0.204  0.720  1.000    0.0       0.017    34.82   1.  -6.    0.0      0.0      0.002     0.0       0.0      0.4
 20       0.6        2.8  0.203  0.719  1.000    0.0       0.017    32.35   0.  -7.    0.0      0.0      0.000     0.0       0.0      0.4
 21       0.6        2.8  0.203  0.718  1.000    0.002     0.017    29.50   0.  -7.    0.0      0.0      0.0       0.0       0.0      0.4
 22       0.6        2.8  0.202  0.717  1.000    0.005     0.017    27.03   0.  -7.    0.0      0.0      0.0       0.0       0.0      0.4
 23       0.6        2.8  0.202  0.717  1.000    0.009     0.017    24.75   0.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
 24       0.6        2.8  0.202  0.716  1.000    0.014     0.017    23.23   0.  -8.    0.0      0.0      0.0       0.0       0.0      0.4
```

TABLE B11. DAILY SNOWMELT OUTPUT DEFINITIONS - CALIBRATION RUN, ENGLISH UNITS

HOUR	Hour of the day, number 1 to 24
PACK	Water equivalent of the snowpack, inches
DEPTH	Snow depth, inches
SDEN	Snow density in inches of water per inch of snow
ALBEDO	Albedo, or snow reflectivity, percent
CLDF	Fraction of sky that is cloudless
NEGMELT	Heat loss from the snowpack, equivalent inches of melt
LIQW	Liquid water content of the snowpack, inches
TX	Hourly air temperature, degrees Fahrenheit
RA	Incident solar radiation, langleys
LW	Net terrestrial radiation, langleys (negative value indicates outgoing radiation from the pack)
PX	Total snowmelt reaching the land surface, inches
MELT	Total melt, inches
CONV	Convection melt, inches
RAINM	Rain melt, inches
CONDS	Condensation melt, inches
ICE	Ice formation at the land surface, inches

APPENDIX C

FORMATTED INPUT SEQUENCE FOR THE ARM MODEL

The Formatted Input Sequence (FIS) option was developed and added to Version II of the ARM Model for use on computers that do not support the namelist input option. The Namelist Input Sequence (NIS) is the only input sequence supported in Version I of the ARM Model.

FIS has been constructed to look as much as possible like NIS. FIS is column-dependent, NIS is not, and so care must be taken when setting up FIS. However, with the format displayed in Table C1 and the description below, most problems can be easily avoided. We recommend using Table C1 as a form for preparing the parameter input for the FIS option, and referring to Tables 5.2 and 5.3 and Section 5 for the parameters required for the model options used.

Table C1 includes shaded boxes, blank boxes, and keywords (not written in boxes). The shaded boxes, which contain parameter names, are not read by the program. They are for the user's convenience as they quickly identify and position parameter values in the input sequence. The shaded boxes can be left blank or used in any manner which helps the user identify the value for any particular parameter. The names given in the shaded parameter boxes in Table C1 are the same as, or abbreviate, the ARM Model input parameter names.

The non-shaded or blank boxes that follow a shaded box are for the parameter value assigned to the parameter name in the shaded boxes. Refer to Table 5.2 and 5.3 for the parameter type (REAL or INTEGER). For all parameters, except those with more than one value, the value of the parameter is placed in the blank box directly after the parameter name. Parameters containing more than a single value (either monthly values or one to 12 sequential values) have the values listed in order after the parameter name box. Examples are K3 and COVPMO: 12 monthly values from January to December; and TIMTIL, TIMAP, and DDG and their related special events (tillage, pesticide application, and pesticide degradation rate). If the number of special events is less than the maximum (12), then the unused blank boxes should either be left blank or given the value of zero. Also, it is always a good idea to set ICHECK equal to ON in the input sequence to check for input errors.

The formatted portion of the nutrient parameter input sequence is identical for both FIS and NIS. The keywords in Table C1 (that is, words not in boxes) are required in the input sequence and specify the parameters that follow the keyword (Section 5.2.1). The nutrient namelist statements have been converted to FIS in the same manner as described above.

When using FIS the ARM Model Version II source code must be modified to use the formatted READ statements. The letter C is removed from column 1 to activate a line of the formatted READ code. Similarly, a C is placed in column 1 of the namelist code to deactivate it when using FIS. The changes to the source code converting from namelist to formatted READ statements are listed below:

Remove C in column 1 for line numbers:

284-312.2
377.64-377.65, 377.7, 6303.-6305.

Add C in column 1 for line numbers:

153.-169.8, 283.01-283.37, 377.62-377.63, 377.69, 6250.93-6250.95,
6302.93-6302.95

The reverse must be done when changing from the formatted READ to the namelist option.

TABLE C1 FORMATTED INPUT SEQUENCE (FIS) FORMAT FOR THE ARM MODEL VERSION II

ARM Model Formatted Parameter Input Sequence

Watershed: ____________________

Run Information: ____________________

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
 watershed identification
 chemical name or run identification
NYCAL=
INPUT=
OUTPUT=
PRINT=
SNOW=
PEST=
NUTR=
ICHECK=
DISK=
IDEBUG=
data identifier
 title identification
DSNFLO=
ENDDISK
 INTRVL=   HYMIN=        AREA=
 BGNDAY=   BGNMON=   BGNYR=
 ENDDAY=   ENDMON=   ENDYR=
 UZSN=         UZS=          LZSN=         LZS=
 L=          SS=         NN=         A=          EPXM=       PETML
 K3=
 INFIL       INTER       IRC=        K24L=       KK24=       K24EL
 SGW=.       GWS=        KV=         ICS=        OFS=        IFS=
SNOWPRINT=
 RADCN       CCFAC       SCF=        ELDIF       IDNS=       F=
 DGM=.       WC=         MPACK       EVAPS       MELEV       TSNOW
 PACK=         DEPTH=
 PETMIN=       PETMAX=       WMUL=         RMUL=         KUGI=
```

TABLE C1 (continued)

ARM Model Formatted Parameter Input Sequence

Watershed: ______________________

Run Information: ______________________

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

COVPMO=

TIMTIL=

YRTIL=

SRERTL=

JRER= KRER= JSER= KSER= SRERI SCMPC

PESTICIDE

APMODE=

DESORP=

PSSZ= PSUZ= PSLZ= PSGZ=

TIMAP=

YEARAP=

SSTR=

CMAX= DD= K= N= NP=

DDG=

YDG=

KDG=

NUTRIENT

TSTEP= NAPPL= TIMHAR=

ULUPTK=

LZUPTK=

REACTION RATES

NITROGEN

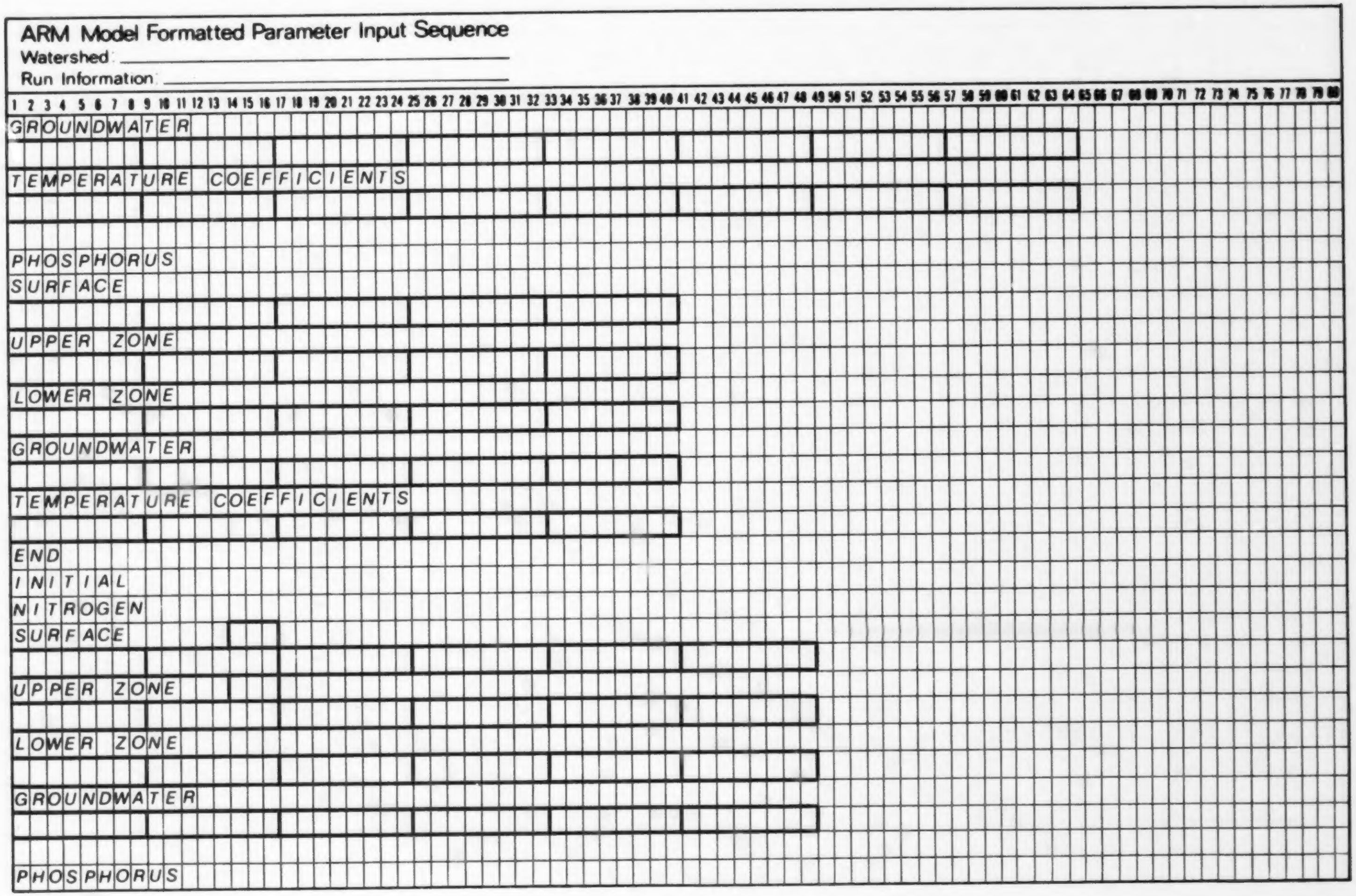
SURFACE

UPPER ZONE

LOWER ZONE

(continued)

TABLE C1 (continued)



ARM Model Formatted Parameter Input Sequence

Watershed: ____________

Run Information: ____________

GROUNDWATER

TEMPERATURE COEFFICIENTS

PHOSPHORUS

SURFACE

UPPER ZONE

LOWER ZONE

GROUNDWATER

TEMPERATURE COEFFICIENTS

END

INITIAL

NITROGEN

SURFACE

UPPER ZONE

LOWER ZONE

GROUNDWATER

PHOSPHORUS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

(continued)

TABLE C1 (continued)

ARM Model Formatted Parameter Input Sequence

Watershed: ____________________

Run Information: ____________________

SURFACE

UPPER ZONE

LOWER ZONE

GROUNDWATER

CHLORIDE

SURFACE

UPPER ZONE

LOWER ZONE

GROUNDWATER

END

APPLICATION

NITROGEN

SURFACE

UPPER ZONE

PHOSPHORUS

(continued)

TABLE C1 (continued)

ARM Model Formatted Parameter Input Sequence

Watershed: ______________________________

Run Information: ______________________________

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

SURFACE

UPPER ZONE

CHLORIDE

SURFACE

UPPER ZONE

LZTEMP=

ASZT= BSZT= AUZT= BUZT=

SZDPTN= UZDPTN= BDSZ= BDUZ= BDLZ= UZF LZF